Modeling and Data Working Group

Systems Analysis of the Data and Models Used for Federal Emergency Management

FINAL REPORT

Contents

Executive Summary

When managing an emergency, whether large or small, federal, state, and local entities must leverage information from a wide range of sources to answer three fundamental questions – "What happened," "Who and what was affected to what degree," and "What needs to be done." In order to effectively address these questions, information resources must first be identified, collated, and made available so as to inform decision making at all levels, from the operational to the strategic levels.

The Modeling and Data Working Group (MDWG) was established in August of 2012 by the Emergency Support Function Leadership Group (ESFLG) to identify and characterize the data and modeling resources that are used across the U.S. interagency during emergency management. The MDWG is chaired by the Director of FEMA's Planning Division, Response Directorate; membership was chosen by the ESFLG and includes subject matter experts, program managers, and program directors representing each of the federal Emergency Support Functions. The scenarios addressed by the MDWG include earthquakes, hurricanes, and improvised nuclear devices (IND). A companion report details the analysis performed on the IND network of resources. This report is limited to the identification and analysis of data and modeling resources related to earthquake and hurricane scenarios only.

In order to capture the breadth of data, analysis tools, and models used by those involved in federal emergency management, a conceptual framework was developed to categorize the information resources in the inventory by their utility. This framework describes the iterative process of data collection, processing, and analysis that produces the operationally relevant information that informs decision making across a wide range of missions. The categorization system contains seven basic types of resources: raw data, event characterization models and analysis tools, situational awareness data, consequence models, impact estimates, decision support tools, and mission specific requirements. These categories of data and models provide context for the widely varied utility of the information resources in the inventory and provide a framework that can be used to describe the flow of information between resource types relative to how and when each resource is used for emergency management.

This report presents an inventory of the datasets and models used to support operational decision making during emergency management of hurricane and earthquake scenarios. This inventory was generated on the basis of over 200 interviews with emergency managers, subject matter experts, and high level decision makers. Nearly 500 data and modeling resources were identified and characterized, of which approximately 130 are included in the current inventory of hurricane and earthquake resources. Each resource is characterized by a series of metadata tags that describe its function, use, and availability. These data about each resource, when compiled, provide the information necessary to a user or potential user regarding the utility of the resource for an emergency management mission.

The network and metadata analysis of the hurricane and earthquake resource inventory, combined with information from interviews with subject matter experts, emergency managers, and senior level decision makers, have revealed three major gaps in how the interagency uses information resources to support decision making during emergency management. Each of the three gaps speaks to an overarching need to translate and link the outputs from existing data and modeling resources to response activities in order to support data-driven decision making across emergency management missions.

1) Lack of operations focused resources, such as cross-sector impact estimates, impact estimate libraries, decision support tools, and mission specific requirements - these resources need to be expanded to support a wider range of missions, and need to be better integrated with the rest of the network.
2) Lack of robust connections within the network; widely used resources, “orphan resources,” impact estimates, and mission specific requirements are poorly connected to the rest of the network - resource integration within the network needs to be improved.
3) Lack of response ready consequence models - incorporating response dynamics into consequence models can be useful for emergency responders to understand the various elements of a response as a whole, and to be able to make informed decisions when prioritizing various response activities.

The corresponding recommended Courses of Action focus on efforts needed to maintain the existing resources and the networks between them and to build a more robust and well-connected network of resources that will help ensure that the necessary information is available to those who need it when they need it for emergency management of hurricanes and earthquakes.

- Perform in-depth analysis and mapping of resources to mission-specific data requirements to determine how the resources in the inventory can inform response actions, and, by extension, the development of preparedness plans
- Develop a Concept of Operations to outline how the resource inventory can be used and to develop a maintenance strategy to ensure that this information is kept up-to-date and accessible to the emergency management community
- Ensure support for highly central resources within the network
- Integrate all resources into the network
- Improve data sharing for situational awareness viewers
- Develop cross sector impact estimate libraries to develop a well-connected and well-functioning network of resources relevant to hurricane and earthquakes
- Develop decision support tools and mission specific requirements to ensure that a robust network of data and modeling resources are available to support operational decision making

- Expand the resource inventory to include additional scenarios, like biological and cybersecurity, to create a robust resource inventory, extend our understanding of how the different resources interact with each other, and highlight potential hazard-specific and mission specific gaps.

The final product of this project is an interactive inventory of the data and modeling resources used by the interagency, accessible via a graphical user-interface. The web-based user interface has been built and can be accessed by authorized users through the FEMA website. A user and maintenance guide that accompanies this report outlines how the resource inventory can be used, and what needs to be done to ensure that it remains up to date. Ultimately, this effort will enable the entire emergency management community to identify and use the resources available to support operational decision making during all phases of hurricane and earthquake events.

Introduction

Introduction Overview

- Effective coordination and leveraging of the information produced by data and models in support of federal interagency emergency management remains a challenge.
- The Modeling and Data Working Group (MDWG) was appointed by the Emergency Support Function Leadership Group (ESFLG) to identify and characterize the data and models used to support operational decision making during emergency management across the interagency.
- In this context, data are defined as repositories of information; models are defined as any program, algorithm, or computational tool that transforms or processes data to produce new information.
- This iteration of the analysis focuses on hurricane and earthquake scenarios; the methods developed will be subsequently applied to additional scenarios.
- The final product is a web-based interactive inventory of the data, models, and analysis tools currently used by the interagency for emergency management.

During all phases of emergency management, critical decisions must be made quickly to save lives and minimize the consequences of an event. Informed decision making is key to success in the field and relies on the accurate synthesis of, access to, and timely dissemination of information to facilitate decision making at all levels.

New data analysis and modeling tools, as well as ready access to these resources, have led to a rapid expansion in the amount of information available to decision-makers across the interagency during emergency management. However, the information produced is not always available in a timely, readily-digestible format designed to facilitate operational decision making. Insufficiently verified information or conflicting results can undermine the ability to effectively leverage available data or information to support real time decision making.

In recognition that informed decision making is key to successful emergency management, the Emergency Support Function Leadership Group (ESFLG) established the Modeling and Data Working Group (MDWG) in August of 2012 to engage stakeholders from across the interagency to collaborate more effectively on issues related to the data and models used to support emergency management. The MDWG was tasked with identifying and characterizing the data and models used to inform operational decision making during emergency management across the interagency. The membership of the working group was chosen by the ESFLG and includes a wide range of emergency managers and subject matter experts from across the interagency, including members from each of the federal Emergency Support Functions (ESF) as identified by PPD-8. The MDWG charter and membership can be found in Appendices 1 and 3, respectively.

The MDWG was initiated not to supplant ongoing interagency efforts, but to incorporate and expand upon them. The strength of this effort lies in the breadth of the membership and the inclusion of all phases of emergency management. In addition, while there are many efforts that have compiled lists of all available resources. By contrast, the goal of this effort is to identify those resources *used* by the interagency and to make information about these resources accessible through an interactive inventory.

Data and models for emergency management

Data, models, and analysis tools play a critical role in parsing the enormous stream of information available for emergency management. These resources inform operational decision-making and enhance all phases of an event, from preparedness and planning to response, recovery, and mitigation. The information gathered is processed through iterative rounds of data collection (e.g. instrument readings, impact maps, damage estimates) and data processing (e.g. weather projections, damage calculations, decision trees). These data collection methods and analysis or modeling tools vary widely, progressing from hazard-specific, scientific data to more mission-specific, operationally relevant information. The terms “data” and “models” are defined differently depending on the types of resources used most frequently. These terms are defined below in the context of this effort, recognizing the broad user and developer communities involved in emergency management.

“Data” is defined as any repository of information used for emergency management. Data, by this definition, includes tools that assist in the presentation or visualization of data without transforming the data itself (e.g., FEMA GeoPlatform, see Appendix 7). Data are classified as raw data, situational awareness data, impact estimates, or mission specific requirements. The data within these categories may be steady-state data describing features of the environment during normal operations or event-specific assessment data collected as an event unfolds. Modeling outputs are not defined here as independent data sets, but are implicitly included with the models that produce them.

Models are defined as any program, algorithm, or computational tool that transforms or processes data to produce new information. Models are classified as event characterization models and analysis tools, consequence models, and decision support tools. Models accept, as inputs, data that are transformed to provide a new type of information (e.g., SLOSH, HAZUS, ShakeMap, see Appendix 7). Models may be predictive, prescriptive, or analytical.

Use cases: Hurricanes and earthquakes

All emergency scenarios require a comprehensive understanding of the data and modeling requirements for planning and operational decision making. The MDWG focused on large-scale hurricane and earthquake natural disaster scenarios typified by Hurricane Ono and the New Madrid Earthquake scenarios, scenarios used as the basis for previous national level exercises. These scenarios are well-understood and frequently practiced, allowing decision makers to clearly articulate their information requirements and define their needs. Therefore, this effort has focused on organizing the available resources so they can be more efficiently and effectively shared, enhancing collaboration and resource-sharing across the interagency to support the information requirements articulated.

Final product

The information collected through interviews during this project has been collated into an interactive inventory of the data, models, and analysis tools that provides an overview of how data and models are used by the federal emergency management community. A web-based user interface has been designed that facilitates queries of the inventory to identify the available resources relevant to the question, mission, or organization. The inventory will be hosted, updated, and maintained by FEMA and made accessible to the federal emergency management community.

Methods

Methods Overview

- Information was collected through over 200 interviews with high-level decision makers, program managers, and subject matter experts in emergency management.
- The results were collated in an inventory of resources, which includes over 20 metadata characteristics describing each resource.
- The metadata in the inventory was processed by quantifying characteristics of the resources and the relationships between them. Network and statistical analyses were performed to support a robust systems-level analysis.

The workflow for this project is depicted in Figure A5.1 and described in brief in this section. See Appendix 5 for a complete description of the methods.

Data collection was performed through interviews with members of the MDWG, other emergency managers, and subject matter experts. In brief, the interviewees were asked how they use data and models to answer questions relevant to their emergency management mission, what data they use to address those questions, and what models or analysis tools they use to process those data. Based on the data collected during interviews, a systems-level analysis of the information requirements was conducted and an ontology, or categorization system, was developed to capture the flow of information between the resource types. The information ontology is described in detail in subsequent sections. Metadata about the specific resources identified during interviews as both operational and used by the federal emergency management community were compiled in an inventory. Metadata characteristics about each resource were defined both through interviews and through additional background research.

Each resource in the inventory is characterized by over twenty metadata tags, including information about the owners and federal users of the resource and the connections between resources. These metadata characteristics provided the basis for two types of analyses: a network analysis based on the upstream and downstream connections of each resource and a statistical analysis of the types of resources. The network analysis is based on network maps, visualizations of the resources and the flow of information between them. Analysis of the metadata characteristics of the resources was used to calculate the types and number of resources in the inventory. A detailed description of the Methods can be found in Appendix 5.

An Information Ontology

Summary

- The use of data and modeling in emergency management is an iterative process.
- Types of data include raw data, situational awareness data, impact estimates, and mission-specific requirements.
- Types of models and analysis tools include event characterization models/analysis, consequence models, and decision support tools.
- Although, the primary unidirectional flow of information is shown in Figure 1, there are many interconnections among the categories, which highlights the flexibility of the framework.

The information needed and used for emergency management is generated through iterative steps of data collection and data processing. At each step, observed data and modeling outputs are aggregated to serve as inputs for the next iteration of data processing. The analysis tools include computationally intensive predictive models to simple, computationally-conservative tools that produce information used to inform narrowly-defined mission-specific decisions.

Emergency management efforts, whether during planning, response, recovery, or mitigation, requires the answer to three fundamental questions: "What happened?", "Who and what was affected to what degree?", and "What needs to be done?" These questions are addressed by different types of data and models and are used by different types of organizations within the federal emergency management community.

To better understand and organize the data and models identified during interviews, each resource was categorized by its function. These functions correspond with different steps in the iterative process of data collection and processing. A framework to understand the flow of information is shown in Figure 1.

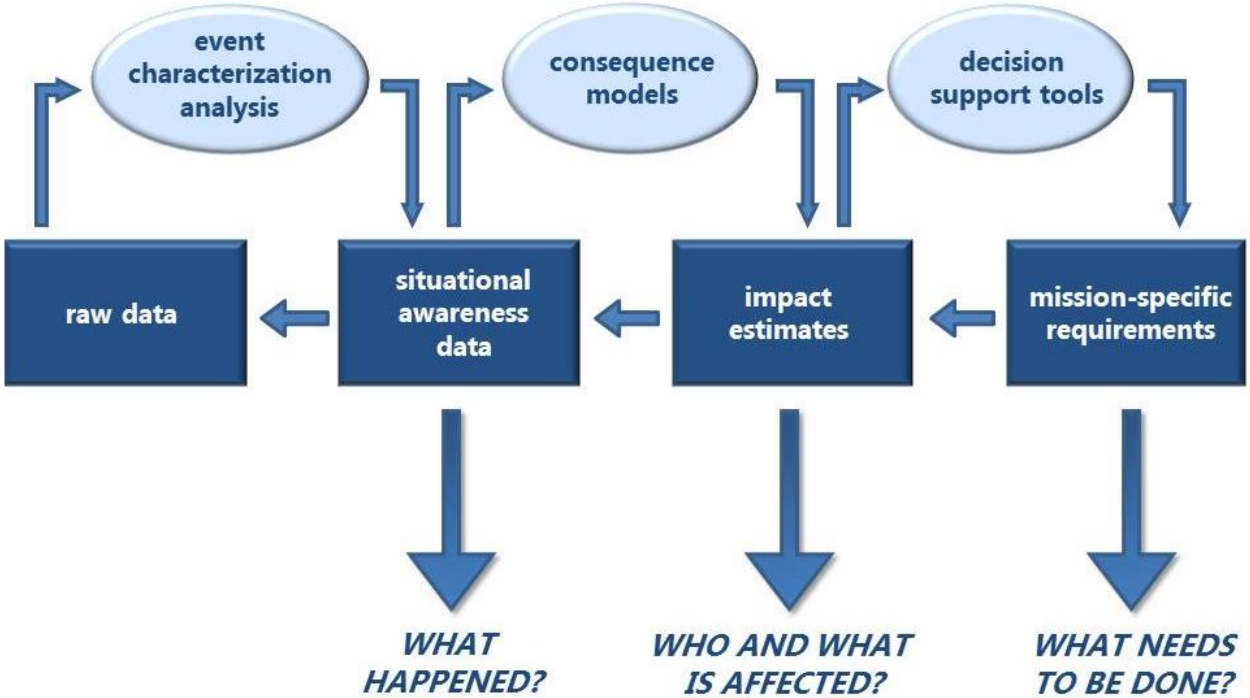


Figure 1. Framework describing the flow of information through iterative rounds of data and modeling. Data sources are shown in dark blue; models and data processing tools are in light blue. Arrows indicate the flow of information. Note: Additional resources provide data and are incorporated into each step but are not shown for simplicity. Examples are described in the text.

Briefly, raw data describe the current state of the world, including real-time weather conditions, locations of fault lines, and absolute magnitude of seismic activity. These data serve as inputs to event characterization models and analysis tools that characterize or predict the location, timing, and severity of an event. The information produced by these models or produced by the processing of raw data is termed situational awareness data and can be used to answer the question of “What happened?” Situational awareness data can be visualized using situational awareness viewers and can also serve as inputs to consequence models. Consequence models are used to estimate impacts to human health, the economy, and infrastructure. The outputs of these models, called impact estimates, answer the question of “Who and what was affected to what degree?” Impact estimates are directly to support decision making or can serve as inputs for decision support tools that guide specific response activities. The information produced by decision support tools define mission-specific requirements. This information quantifies the personnel and resources needed to support narrowly defined emergency response missions, and can be used to answer the question of “what must be done” after an event.

All categories of data with the exception of raw data are used as the basis for decision making. Although the flow of information, as described above, culminates in mission-specific requirements, emergency managers often refer to other data types, including situational awareness data and impact estimates, when making decisions. For example, FEMA establishes initial evacuation zones and timelines based on situational awareness data derived from the SLOSH inundation model at NOAA. Similarly, FEMA Individual Assistance consults Preliminary Damage Assessment data (an impact estimate) collected during an event to predict the size of its recovery programs.

The bulk flow of data and information moves forward and step-wise through the information categories as described by the framework. However, some data or information also move in feedback loops or “skip” steps. For example, as real-time event data are collected and processed, this information can be used to verify and validate the outputs of predictive models and previous analyses. These feedback loops provide critical data for verification, validation, and the continual process of updating modeling parameters using real-time data. For example, as high water marks or surge data are collected during and after a hurricane, inundation models can be re-run with these updated inputs to improve the fidelity of the model and the usefulness of the information produced. In addition to these feedback loops in the flow of information, some models pull data from resources other than the one immediately upstream of it in the flow. For example, HAZUS is a consequence model that accepts not only situational awareness data, but also US Census Data, which is a raw data resource. In addition, steady-state raw data describing infrastructure or road maintenance may not be used by event characterization models, but are important data feeds underlying many of the consequence and decision support tools.

Each category in the flow of information is described in detail below, including examples specific to hurricanes and earthquakes. These examples are not intended to be all inclusive and are used here for the purpose of illustration. A comprehensive inventory of the modeling and data resources is included in the Data and Models Resource Catalog (Appendix 7).

Raw Data

Raw data are defined as unprocessed data that describe the characteristics of a specific hazard or as steady-state data that characterize the environment prior to and during an event. These data include static look-up tables, on-the-ground assessment data, steady-state data (bridge location databases), or real-time data (observational weather data). The majority of the modeling performed for the purposes of emergency management relies heavily on raw data produced by a small number of specialized agencies.

Raw data are collected in a variety of ways, ranging from the use of pre-deployed instrumentation assets to phone calls over which proprietary and privileged information is exchanged. All social media or crowd-sourced data are collected as raw data. While most raw data is open access and available online, some raw data is proprietary and only selectively shared, if shared at all. While many types of event-specific raw data are collected before, during, or immediately after an event, steady-state raw data such as the Quaternary Fault and Fold Database produced by USGS are also used regularly in support of emergency management.

Event Characterization Models and Analysis

Event characterization models and analysis tools characterize or predict the location, timing, or severity of an event. These models are used to consider specific characteristics of past, impending, or current hazards. They often compile raw data to identify patterns that define an event, or they characterize attributes of a developing event. Event characterization models include weather forecast models such as those produced by NOAA, but also include models such as SLOSH (Sea, Lake, and Overland Surges from Hurricanes), which incorporates observational weather data to estimate which areas are going to be inundated with flood waters when, and with how much water.

Event characterization models and analysis are required to guide the vast majority of downstream decisions, regardless of the specific mission. The outputs can drive high-level decisions, including whether or not an event requires an emergency response. They also drive concrete decisions, such as the choice to evacuate patients from hospitals where generators will likely be flooded by a storm surge. SLOSH (described above), for example, is often suitable to inform early decisions like patient evacuation.

Situational Awareness Data

Situational awareness data are used during or after an event to characterize who is or was impacted by what, where, and when. Situational awareness data can be the outputs of event characterization models that process raw data or may be obtained through the extraction, transformation, or analysis of raw data such that they can be used to describe or characterize the event. For example, raw data inputs for weather forecast models can produce situational awareness data in the form of weather forecasts used to predict the location, time, and severity of a hurricane. Similarly, seismographic instrumentation networks can be processed to produce ground-shaking maps that illustrate the geographic extent and severity of ground shaking data.

Situational awareness data are often collated and visualized in map-based situational awareness viewers. These viewers overlay real-time event data that characterize and geo-locate the hazard with infrastructure and population data, as well as any mission-specific or agency-specific data.

Consequence Models

Consequence models predict the impacts of a hypothetical or actual event. Impacts that can be modeled include, but are not limited to, economic loss, infrastructure damage, health effects, and supply chain disruptions. These models are typically event-specific, though some support consequence predictions for multiple hazard types. For example, HAZUS is a consequence model produced by FEMA Mitigation designed to predict the economic impacts of earthquakes, floods, and hurricanes. It is a flexible platform that accepts a wide variety of data feeds. By contrast, PAGER, a USGS product, models only the losses from structural damage caused by earthquakes.

In some cases, the applications of consequence models have been extended well beyond the uses for which they were originally intended. For instance, HAZUS was designed to provide economic loss estimates for FEMA Mitigation. However, this consequence model is being used throughout the interagency to estimate more general event impacts in support of a wide array of mission areas. Its outputs, either as-is or with further processing, are used to guide estimates of the volume of temporary housing resources that will be required, the populations affected, and even the number of loan officers required to field the applications that are expected to be filed with the Small Business Administration. This expansion in utility suggests that HAZUS serves as an important backbone for decision making in emergency management across the federal interagency.

Impact Estimates

Impact estimates define the consequences of a specific event. This information can either be derived from post-event assessment data or as the outputs of consequence models that predict impacts, including economic loss, infrastructure damage, health effects, or supply chain disruptions. Impact estimate data resources include libraries of consequence model outputs (e.g., the Coastal Flood Loss Atlas) and archives of historical assessment data. These data directly inform the response and recovery phases of an emergency and are collected, processed, and used broadly across the interagency.

Assessment data collected post-event (a form of impact estimate) can be incorporated into iterative model runs and used to update the inputs of characterization and consequence models as the event progresses. In the best case scenario, these data are made available to those making response and recovery decisions to facilitate the verification of the predictive modeling outputs and to continually re-assess response and recovery activities over the course of the event.

Decision Support Tools

Decision support tools are models or analysis tools that calculate the resources necessary to support mission-specific activities. These models are often developed and employed by agencies or divisions with highly-specific mission areas. For example, the Army Corps of Engineers has developed a tool that predicts the amount of debris likely to be deposited in public roadways in regions impacted by flooding and calculates the number of dump trucks and other equipment required to remove that debris.

Decision support tools can use the data produced by either event characterization or consequence models to determine the specific actions required to respond to an event. For instance, HURREVAC, a decision support tool developed through a partnership between FEMA, NOAA, and USACE, calculates when specific regions will need to be evacuated based on predictions of hurricane track, severity, and landfall time on the basis of the National Hurricane Center’s forecasts and the outputs of the SLOSH inundation model. As another example, SAROPS, a decision support tool used by the US Coast Guard, leverages data to generate optimal locations for maritime search and rescue activities.

Mission-Specific Requirements

Mission-specific requirements quantitatively define the resources necessary to support a given mission, including materials and personnel. Most often, mission-specific requirements consist of the outputs of decision support tools like the USACE debris estimating model. Others are standalone resources that track the availability of disaster relief supplies, like the LSCMS database maintained by FEMA. Still others, like the DSARS database used by the Red Cross, report staffing needs.

During an event, most mission-specific requirements will be calculated on the basis of post-event assessment data. For example, USACE calculates the number of tarps required to provide temporary roofing on the basis of impact estimate data collected post-event. However, an analysis of historical data combined with predictive modeling can also be used to guide pre-event purchasing decisions and provided an evidence-basis for resource allocation during the planning and preparedness activities.

Results

The MDWG was tasked with identifying and characterizing the data and modeling resources used by the federal interagency and develop an inventory containing the information collected. This information was analyzed to determine how the resources are used, how they are connected, and how they function together to provide the information needed when planning for and responding to emergencies. To perform the analysis, the metadata characteristics of each resource, such as resource type, owner and user data, were collated and quantified. The metadata were analyzed to determine the types of resources used, the total number of linkages between each resource, and the major users and producers of the information that enables decision making within the federal interagency during emergency management. By quantifying the metadata describing the linkages between the resources, network maps were built and network analyses were performed.[1] A detailed description of the methods can be found in Appendix 5. The results of the analysis are described below.

Flow of information within the network

Resource network by resource type

Summary

- The hurricane and earthquake resource networks are generally well-connected and dominated by a relatively small number of widely used resources.
- In both networks, there is a subset of resources, termed “orphan resources” that are completely unconnected to other resources in the network.
- These network maps visually highlight those resources that are already well-integrated and widely used and those resources that are poorly connected. This analysis provides immediate feedback regarding successes and areas for improvement related to interagency data sharing.

Network maps provide a visual representation of how information moves between resources to support decision making in the context of emergency management at the federal level.

[1] Network analysis is a systems-level analysis used to evaluate the robustness and interconnectedness of the resource network.

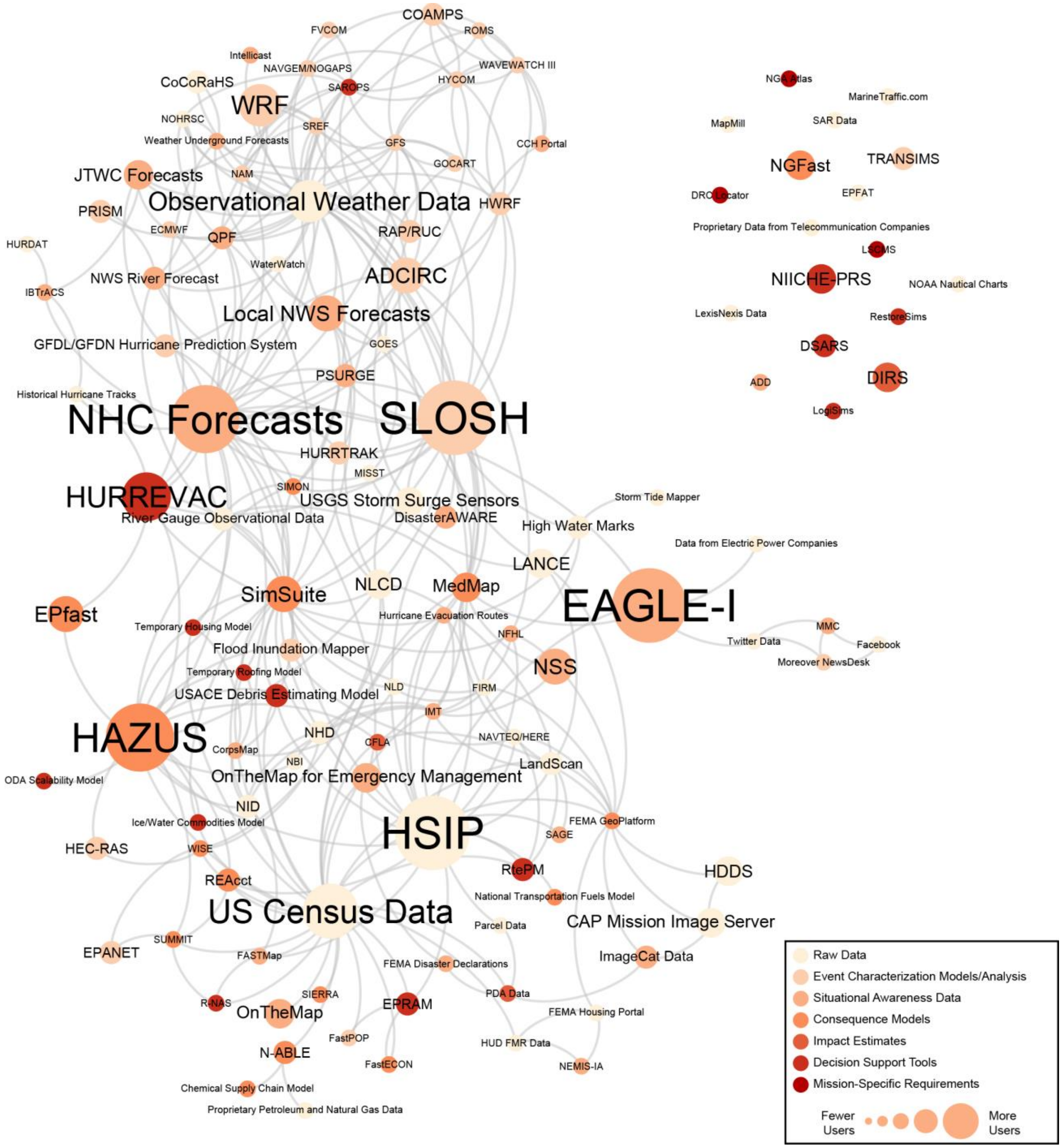


Figure 2. Hurricane resource network colored by resource type. In this network, each node (circle on the graph) represents a resource in the inventory and is sized proportionally to the number of organizations that use that resource across the federal interagency. Edges, the curved lines connecting two nodes, represent information moving between resources. Information flows clockwise between resources.

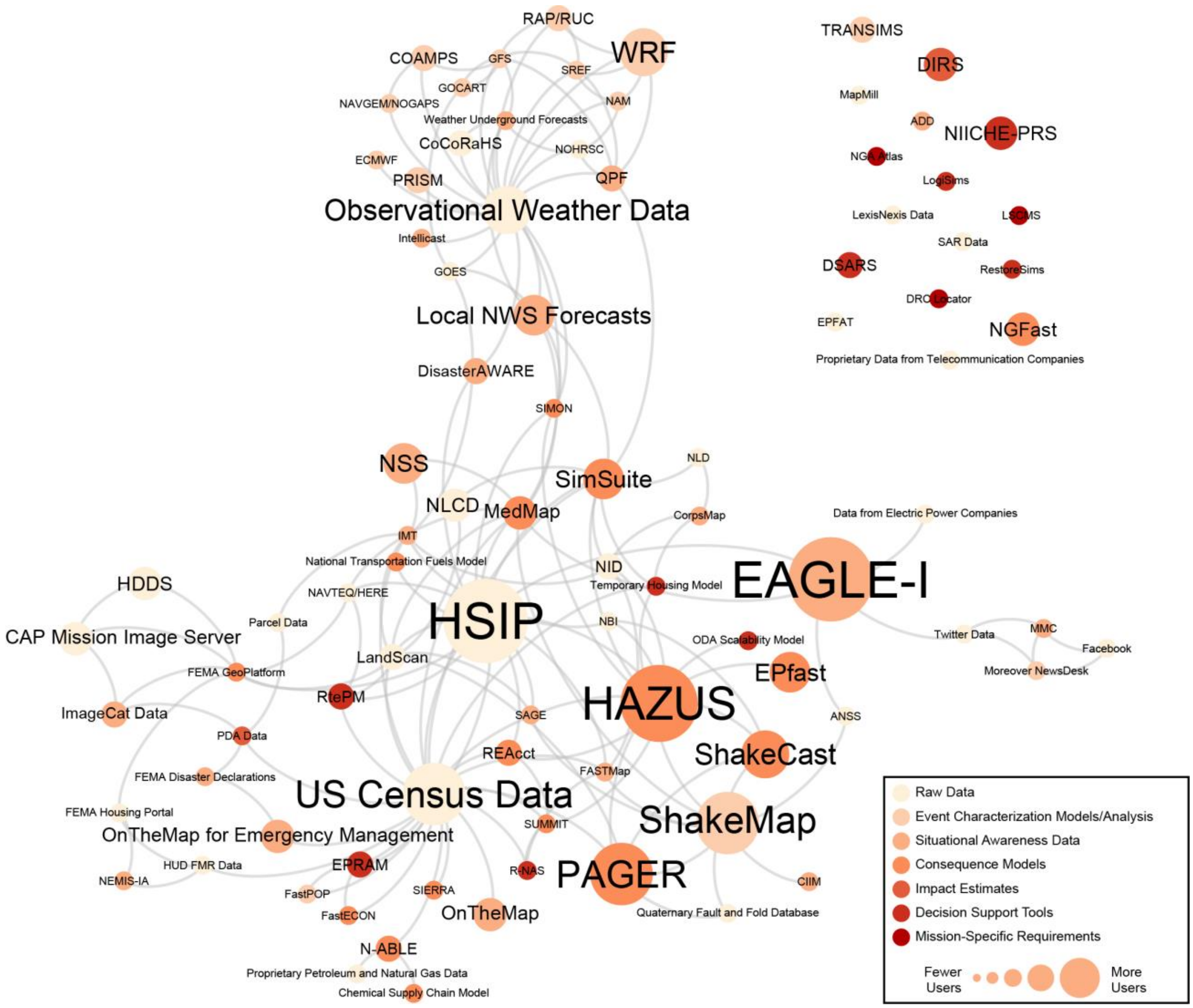


Figure 3. Earthquake resource network colored by resource type. In this network, each node (circle on the graph) represents a resource in the inventory and is sized proportionally to the number of organizations that use that resource across the federal interagency. Edges, the curved lines connecting two nodes, represent information moving between. Information flows clockwise between resources.

Most widely-used resources

As shown in Figures 2 and 3 and in Table 1, a large number of federal agencies rely on a relatively small number of widely used resources (as indicated by the size of the node). Of the most widely used resources in both the hurricane and earthquake networks, about half are multi-hazard tools. The most widely-used resources in the resource networks are those that define the hazard and the immediate impacts. These resources include raw data sources for infrastructure and population, hazard-specific event characterization models, situational awareness tools, and cross-sector consequence models.

Notably, the most heavily used resource in both networks is EAGLE-I, a relatively new situational awareness viewer developed by the Department of Energy that provides real time information about electricity outages. EAGLE-I is widely used in part because it provides information that was not previously available about the stability of a sector with consequences that have a large impact on all other sectors. However, EAGLE-I is not yet well-integrated into the interagency information networks, unlike most of the other most widely used resources (see Figure 2 and 3). Better integration of the data from the resource would help ensure that operational decisions are made on the basis of this information.

Table 1. Resources with the most federal agency users. Resources with at least 7 federal agency users are listed in decreasing order of number of users. Resources with the same number of users are listed alphabetically.

Resources	Users	Hazards	Resource Types	Descriptions
EAGLE-I	10	All-Hazards	situational awareness data	Monitors, aggregates, and displays energy system data
HSIP	10	All-Hazards	raw data	Critical infrastructure and key resource data
SLOSH	10	Hurricane	event characterization models/analysis	Estimates storm surge heights
HAZUS	9	Multi-Hazard	consequence model	Estimates economic impacts of select natural disasters
NHC Forecasts	9	Hurricane	situational awareness data	Predicts hurricane intensity and track
PAGER	7	Earthquake	consequence model	Predicts the economic and fatality estimates from an earthquake
ShakeMap	7	Earthquake	event characterization models/analysis	Ground motion and shake intensity maps
US Census Data	7	All-Hazards	raw data	Regional populations, demographics, and survey items

Orphan resources

In both networks analyzed, a subset of resources are not linked to any other resources (Figure 2 and 3, Table 2). These "orphan" resources are used by the federal interagency but are not connected to any other resources in the inventory: they neither pull data from other resources nor is the data they used to feed any other resource.

Interestingly, the majority of orphaned resources fall at either end of the flow of information. The raw data orphans contain data that have not yet been incorporated into event characterization or consequence models. These datasets, if linked to relevant downstream resources, may be useful to refine and improve the parameters of existing models. Similarly, decision support tools and mission specific requirement resources are over-represented in the list of orphans. This lack of integration is of concern as these resources must be linked to upstream event characterization and consequence analyses in order to ensure that the calculations are based on the best available real-time data about the event. This gap is described in more detail in the Gap Analysis section of this report.

Table 2. Orphaned resources for Hurricane/Earthquake/All-Hazards Inventory. These resources do not have any upstream or downstream linkages within the inventories listed in the 'Hazards' column. Resources are ordered alphabetically. (See Appendix 7 for details on each resource.)

Resources	Hazards	Resource Types	Descriptions
ADD	All-Hazards	situational awareness data	Federal Emergency Management Agency automated database for personnel tracking
DIRS	All-Hazards	impact estimate	Communications infrastructure information reporting system
DRC Locator	All-Hazards	mission-specific requirements	Locations and statuses of Disaster Recovery Centers
DSARS	All-Hazards	impact estimates; mission-specific requirements	Automated reporting system for Federal Emergency Management Agency disaster services
EPFAT	All-Hazards	raw data	Dataset of facility emergency power requirements
LSCMS	All-Hazards	mission-specific requirements	Federal Emergency Management Agency database for disaster relief supplies tracking
LexisNexis Data	All-Hazards	raw data	Census block-level insurance information from LexisNexis
LogiSims	All-Hazards	decision support tool	Resource allocation decision support software
MapMill	All-Hazards	raw data	Aerial imagery converted to maps by crowdsourcing

MarineTraffic.com	Hurricane	raw data	Shows information on vessels including location, type, speed, direction, destination and origin
NGA Atlas	Earthquake; Hurricane	mission-specific requirements	Disaster-specific atlases including maps and imagery
NGFast	All-Hazards	consequence model	Natural gas simulation tool to estimate impacts of pipeline breaks
NOAA Nautical Charts	Hurricane	raw data	Used to track buoy locations, sunken vessels, and ocean or port depths
Proprietary Data from Telecommunication Companies	All-Hazards	raw data	Selectively shared, proprietary telecommunication data
RestoreSims	All-Hazards	decision support tool	Resource allocation decision support software
SAR Data	All-Hazards	raw data	Synthetic Aperture Radar data describing the Earth's surface
TRANSIMS	All-Hazards	event characterization models/analysis	Transportation Analysis and Simulation System for regional transportation modeling

Number of resources based on the flow of information

Summary

- For both hurricanes and earthquakes, there are only a limited number of impact estimate and mission-specific requirement datasets or libraries. These resources are needed to directly inform operational decision support.
- Quantifying the types of resources available highlights system-level gaps. This information can be used by strategic planners to determine where best to focus efforts when developing new resources.

Network maps provide a broad, systems-level view of the resources and the connections between them. Quantifying the number of resources that are available within each resource type can reveal the bulk of information between resources of each category. The number of resources in each information category is shown in Figure 4.

For both hurricane and earthquake scenarios, there are many more resources in the categories early in the flow of information (raw data, event characterization, and situational awareness). To some degree, this trend is not surprising: a great deal of raw data from a wide range of sources is necessary to feed robust event characterization models. For example, the hurricane forecasts published by the National Hurricane Center are generated by collecting and processing large volumes of observational weather data and combining and comparing the outputs of a large number of weather models, a process that significantly improves the accuracy and resolution of the forecasts.

By contrast, there is a marked lack of resources that function as sources for impact estimate data or mission-specific requirements data. Those resources that do include impact estimates or mission-specific requirements (which are also outputs of consequence models and decision support tools) typically are multi-functional resources; serving as a library or repository of modeling results and data is not their primary function. Therefore, these results are not as readily accessible as they would be through a resource built for that purpose. These results highlight a need for tagged, searchable libraries of authoritative runs of consequence models and decision support tools.

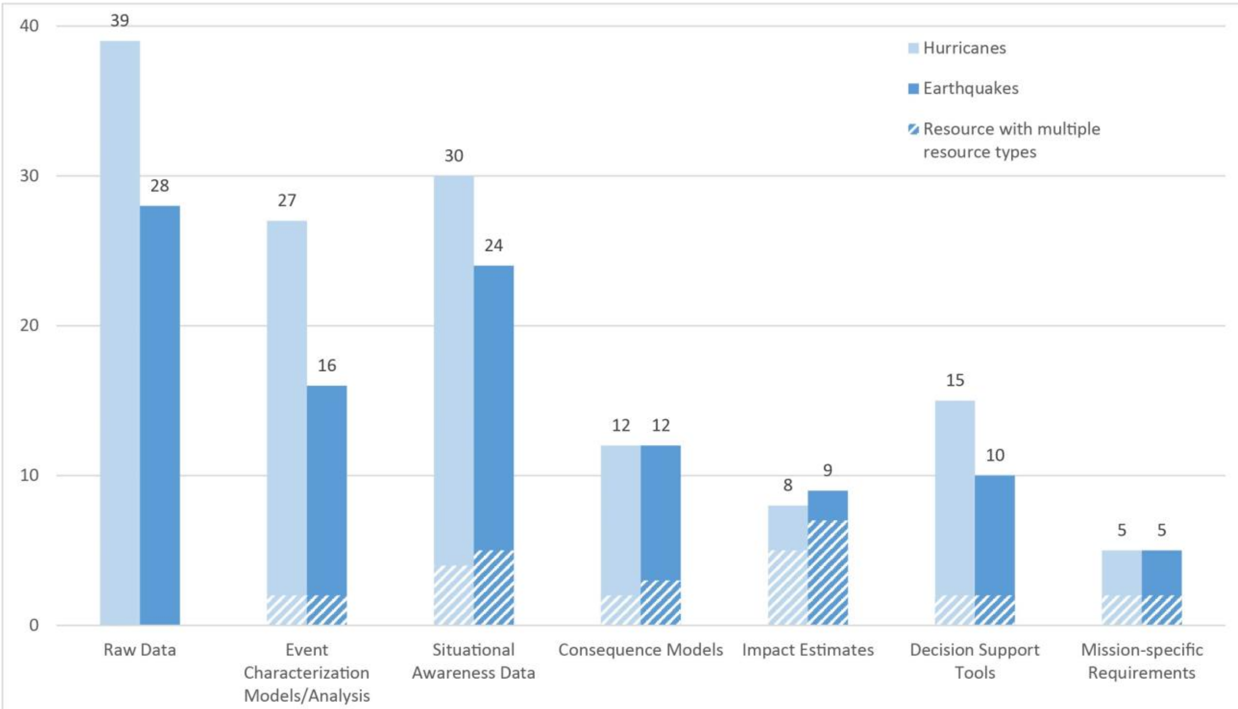


Figure 4. Number of resources by type. The number of used resources in each category is shown. Resources only relevant to hurricanes are shown in dark blue. Resources only relevant to earthquakes are shown in light blue. The number of resources that function as more than one resource type is indicated by white hatch marks.

Resources Described by Multiple Resource Types

The vast majority of the resources in the inventory fall in only one category within the flow of information. However, a small subset of the resources provides data or performs modeling or analysis that is more accurately described by more than one category (see Figure 4 and Table 3).

Table 3. Resources with multiple resource types the inventory.							
Resources	Raw Data	Event Characterization Models/Analysis	Situational Awareness Data	Consequence Models	Impact Estimates	Decision Support Tools	Mission-Specific Requirements
DSARS					X		X
FEMA GeoPlatform			X		X		
MedMap			X		X		
PAGER				X	X		
ShakeCast			X		X		
SIMON			X		X		
SimSuite		X	X	X	X	X	X
SUMMIT		X		X		X	

Of the resources that fall in more category, all the resources, except for ShakeCast, are tagged as all-hazards resources. Five of these multi-tagged resources are agency-specific situational awareness viewers that incorporate the outputs of consequence models, and so are tagged as both situational awareness data and impact estimates: FEMA GeoPlatform (FEMA), MedMap (HHS), ShakeCast (USGS), SIMON (State), and SimSuite (USACE). SUMMIT (DHS/FEMA) is designed to combine multiple model types to generate comprehensive modeling outputs with code calculating results related to each category. DSARS (Red Cross) serves as both a source of impact estimate data as well as mission specific requirement as it is used to track damage assessments, supply needs, and staffing needs for the American Red Cross. USACE's SimSuite provides utility across the entire flow of information from event characterization modeling to mission-specific requirements. This resource wraps both models and datasets into one large resource that transforms hazard-specific raw data into situational awareness, consequences, and mission-specific requirements for USACE.

Bulk flow of information

Summary

- The majority of information flows from raw data into all downstream resource types.
- There is limited information passed from consequence models to downstream resources and very little flow of information into mission-specific requirements.
- Knowing how information flows through the network highlights to the operational user which resource types are not as connected within the network.

To understand how information moves through the network of resources the bulk flow of information from raw data to mission-specific requirements was mapped (see Figures 5 and 6). The analysis of bulk information flow highlights that the majority of information flows from raw data into downstream resources. Some information moves in a strictly iterative manner from one resource type to the next, but, in addition, each type of information feeds other categories downstream.

Importantly, this visualization highlights a major gap in the flow of information: there is limited information passed from consequence models to downstream resources and very little flow of information into mission-specific requirements. This lack of connectedness indicates a failure to incorporate data from upstream resources that provide real-time information, and suggests a lack of communication between those performing real-time event characterization and consequence modeling and those performing mission-specific operations.

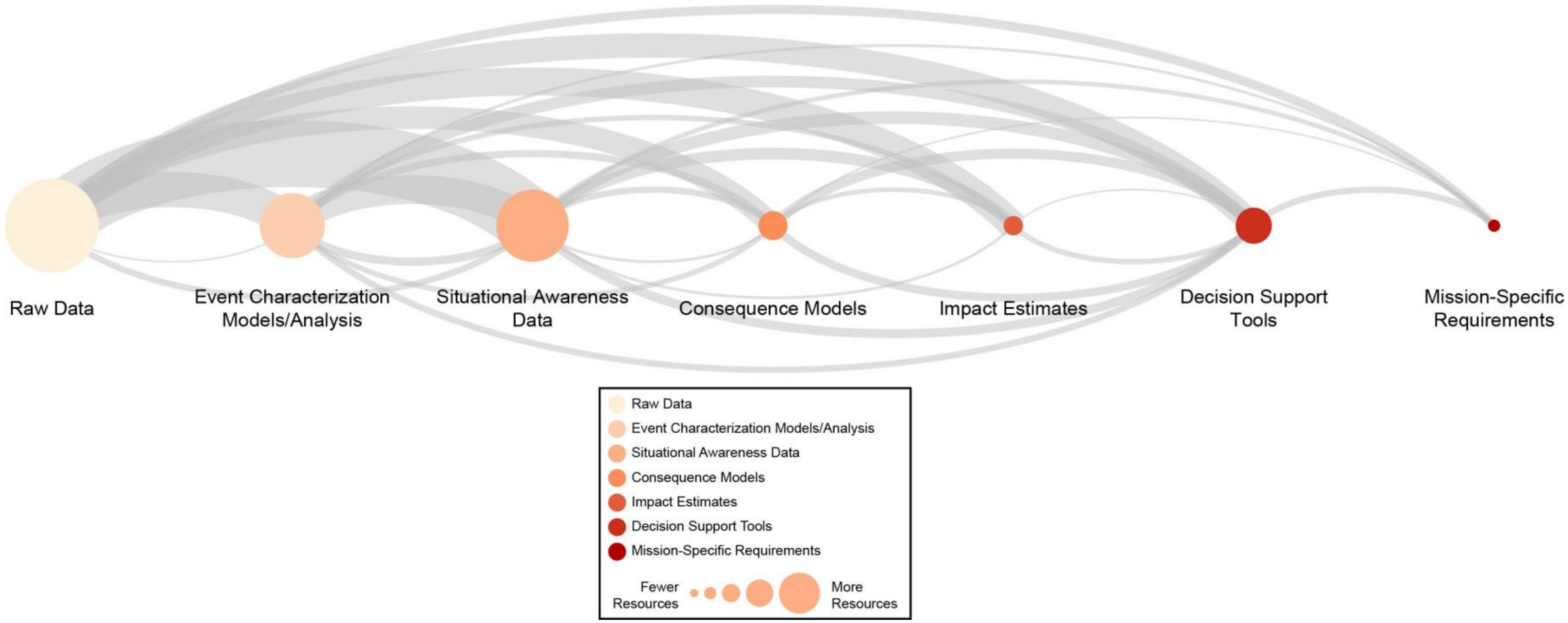


Figure 5. Bulk flow of information for hurricane scenarios. Nodes represent each resource category and edges represent the flow of information from a resource in one category to a resource in another. The size of the nodes is proportional to the number of resources of that type. Nodes are colored from light to dark based on the position of the resource category in the flow of information. The width of each edge is proportional to the number of connections between the two resource types. Information flows clockwise. Resources tagged as multiple resource types were duplicated and separated into each of those resource types to more accurately represent how data is processed.

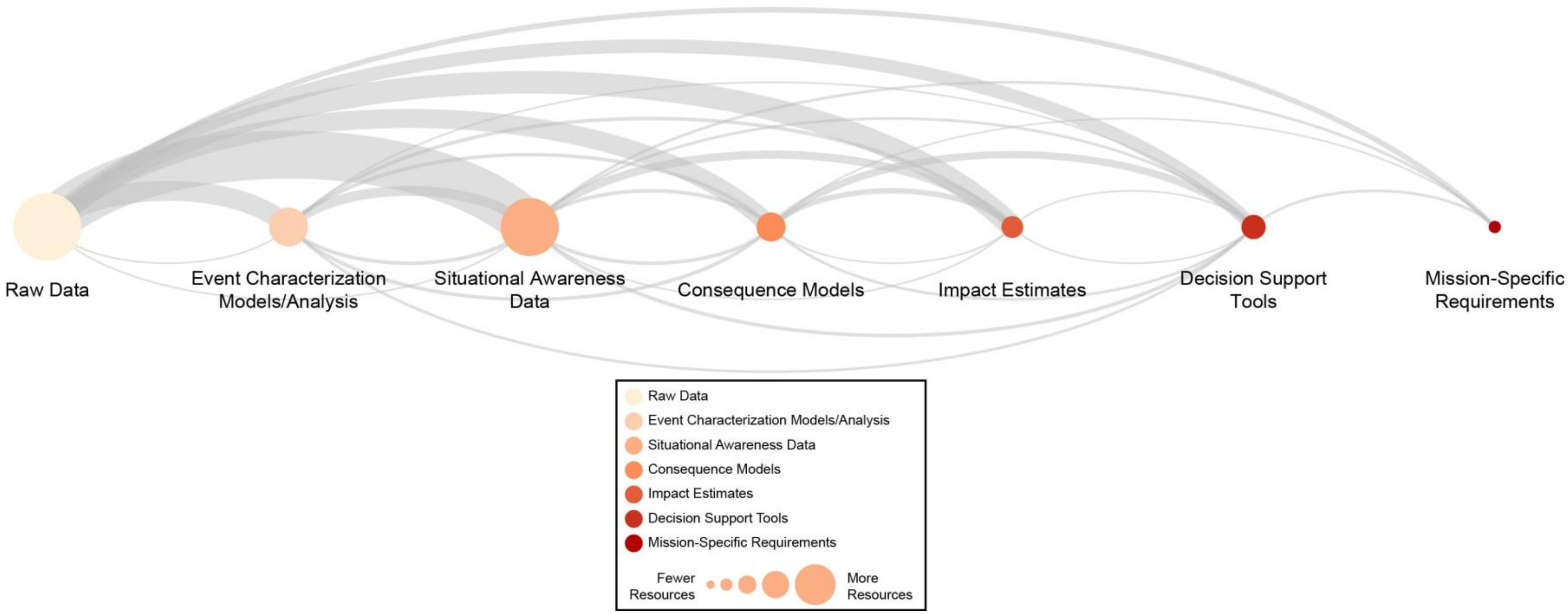


Figure 6. Bulk flow of information for earthquake scenarios. Nodes represent each resource category and edges represent the flow of information from a resource in one category to a resource in another. The size of the nodes is proportional to the number of resources of that type. Nodes are colored from light to dark based on the position of the resource category in the flow of information. The width of each edge is proportional to the number of connections between the two resource types. Information flows clockwise. Resources tagged as multiple resource types were duplicated and separated into each of those resource types to more accurately represent how data is processed.

Resource centrality

Centrality of individual resources

Summary

- Flow of information through the hurricane and earthquake networks depend on a few resources that are highly central, serving as information bridges between other resources.
- The most widely used resources are typically the most central resources, with a few exceptions; only a few highly central resources are not widely used.
- Identifying highly central resources within the network highlights the importance of investments to maintain and update these resources. Loss of these highly central resources would significantly reduce information sharing throughout the whole network.

As information moves through a network, there are some resources that more frequently act as a bridge linking two other resources. This characteristic describes how integral the resource is to the network and can be quantified by its "centrality" (see a detailed definition of betweenness centrality in Appendix 5).[2] Centrality is largely determined by the number and diversity of upstream and downstream resources in the network. Though not the only indicator of critical resources within the network, the most central resources in the network are those that are most critical for efficient flow of information.

As shown in Figure 7 and 8, HAZUS is one of the most central resources in both hurricane and earthquake networks. The model pulls from a large number of resources that include observational weather data, outputs of weather forecasting models, population, and infrastructure data and uses these data to calculate the predicted impacts of a range of natural hazards. Though the model was designed as an economic loss model, the outputs are used broadly across the interagency to estimate a wide range of sector-specific impacts from infrastructure damage to population impacts and as the basis for debris deposition calculations and personnel requirements. Similarly, the other most central resources are event characterization models such as weather, inundation, and ground shaking models and raw data resources such as the infrastructure data aggregator, HSIP. Notably, with the exception of US Census Data and EAGLE-I, the most widely-used resources (Table 1) are also some of the most central resources.

Not all highly central resources are widely used. For example, the Global Forecasting System (GFS) and the Quantitative Precipitation Forecast (QPF) are two highly central weather forecasting systems that are used only by NOAA and FEMA, respectively. Both resources transform observational weather data

[2] As described in Appendix 5, the degree of integration of each resource within the network can be quantified by betweenness centrality, a common centrality measure that characterizes how often a node is found between other nodes in the network.

into weather forecasts essential for dispersion modeling and other rounds of event characterization. Despite having few users, the high centrality of these GFS and QPF indicate their importance as information bridges within the network.

Low centrality measures do not necessarily indicate a lack of importance of the resource within the network. For example, Figure 7 shows that a number of heavily used raw data resources within the network, like Observational Weather Data or US Census Data, have low centrality measures. Resources at the beginning (raw data) or end (mission specific requirements) of the flow of information are rarely information bridges and generally are expected to have low centrality values. Nonetheless, these resources are widely used and serve as important sources of data or mission-specific information.

However, low centrality values for widely-used resources, particularly for resources that fall in the middle of the flow of information, can indicate network components that could be better integrated and linked. For example, the situational awareness data resource, EAGLE-I, has the largest number of users (see Table 8), but a very low centrality value. As situational awareness data, EAGLE-I would be expected to connect upstream to event characterization models and downstream to consequence models and would be expected to be an important information bridge. A better integration of these resources into the network could improve how information is processed, analyzed, or used by the interagency.

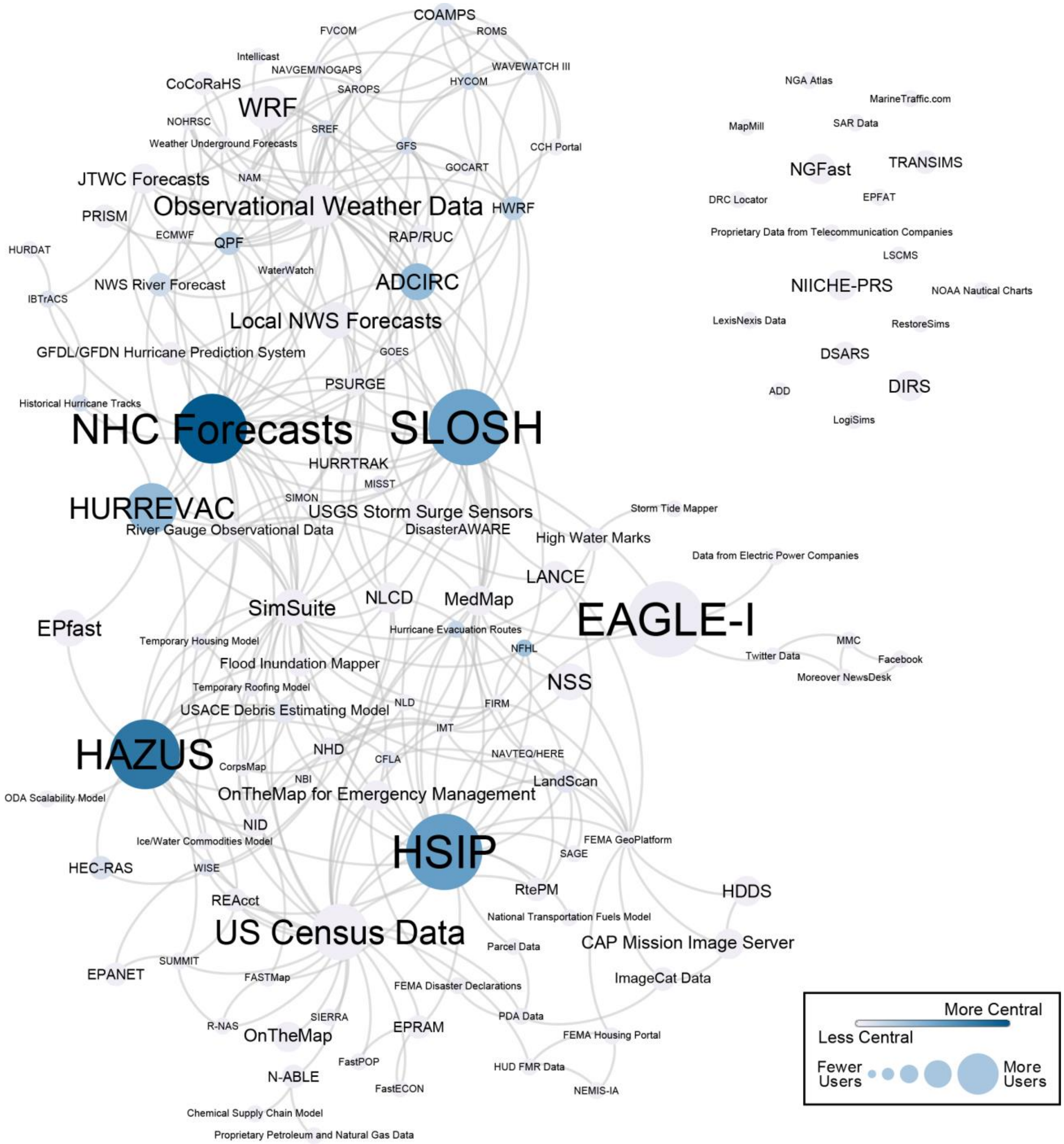


Figure 7. Hurricane network centrality. In the hurricane network, each node (circle on the graph) represents a resource in the inventory and is sized proportionally to the number of organizations that use that resource across the federal interagency. Darker blue represents more central resources, while lighter blue represents less central resources. Edges, the curved lines connecting two nodes, represent information passing from one resource to

another. The edges curve in a clockwise fashion, distinguishing which resource is the source and which is the target of the information. Only hurricane and all-hazards resources from the inventory appear in this network.

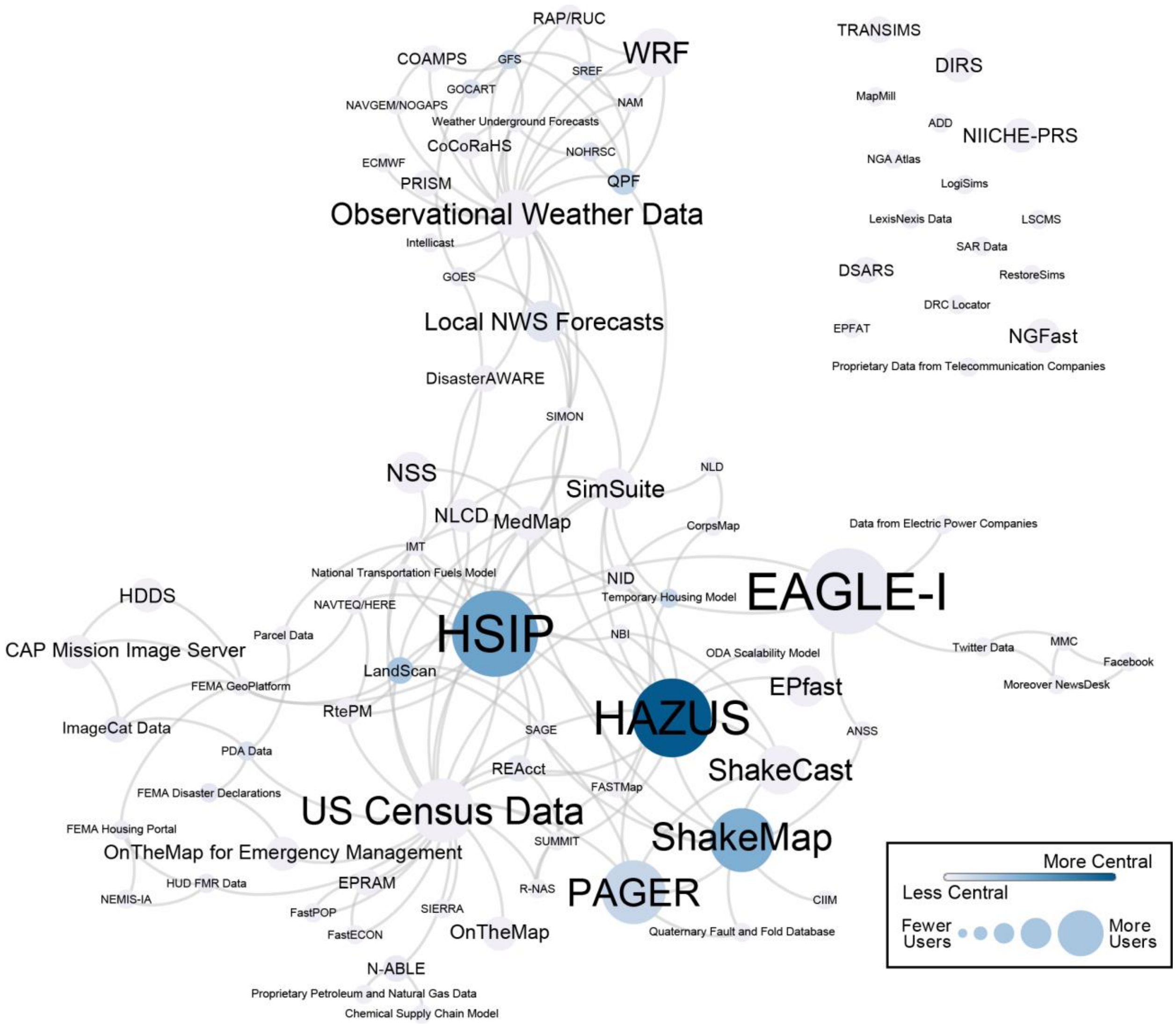


Figure 8. Earthquake network centrality. In the earthquake network, each node (circle on the graph) represents a resource in the inventory and is sized proportionally to the number of organizations that use that resource across the federal interagency. Darker blue represents more central resources, while lighter blue represents less central resources. Edges, the curved lines connecting two nodes, represent information passing from one resource to another. The edges curve in a clockwise fashion, distinguishing which resource is the source and which is the target of the information. Only earthquake and all-hazards resources from the inventory appear in this network.

Resource users and owners

Data and models are useful only if they are used. Although lists of data and modeling resources available to the federal emergency management community have been generated previously, none have identified which of those resources are used and by whom. This information is also valuable when determining how data and models are used to support decision making, as different users use resources for different purposes. To address that gap, interviewees across the federal interagency were asked which resources they use in the context of their emergency management mission, as well as which resources were developed or produced by them. Those resources identified as being used directly to support emergency management by at least one federal agency were included in the inventory.[3] The agency or agencies using the resource directly are described as users.[4] The results of these analyses are shown in Figure 9, 10, and 11.

Federal users and resource types

Summary

- FEMA is the largest user of interagency resources, and uses resources from all seven resource types.
- Other organizations have more specific missions and, therefore, use a subset of resources relevant to that mission. For example, NOAA and USGS, tend to use resources towards the beginning of the flow of information. USACE, on the other hand, uses more processed information like decision support tools.
- Knowing which agencies use what types of resources can help to prioritize and develop robust engagement plans to ensure that information is shared seamlessly between agencies during an event.

In considering how data and models are used to inform emergency management decisions, it is useful to know what types of resources are being used by whom. Figure 9 shows the top six federal-level users and the resource types they use.

FEMA is the largest user of interagency resources and uses information from seven all resource types. This observation is not surprising, because FEMA is tasked with coordinating efforts across all

3 See the Methods section, described in detail in Appendix 5 for a complete description of guidelines for including resources in the inventory.

4 For the purposes of our analysis, users are defined as federal government agencies or organizations explicitly included in the Emergency Support Functions, as described in the National Response Framework. Note that a resource is defined as used by an agency only if they use the resource directly; upstream resources or feeds of used resources are not included. Users can also be calculated by including not only the number of direct users, but also those users of all resources that provide inputs for a given resources. We refer to this latter method as calculating "cumulative users."

emergency management missions. Other organizations have more specific missions and therefore use a subset of resources relevant to that mission. For example, National Oceanic and Atmospheric Agency (NOAA) and U.S. Geological Survey (USGS) mostly use resources towards the beginning of the flow of information, like raw data and event characterization models. On the other hand, the US Army Corps of Engineers (USACE) is a proportionally larger user of more processed information like decision support tools.

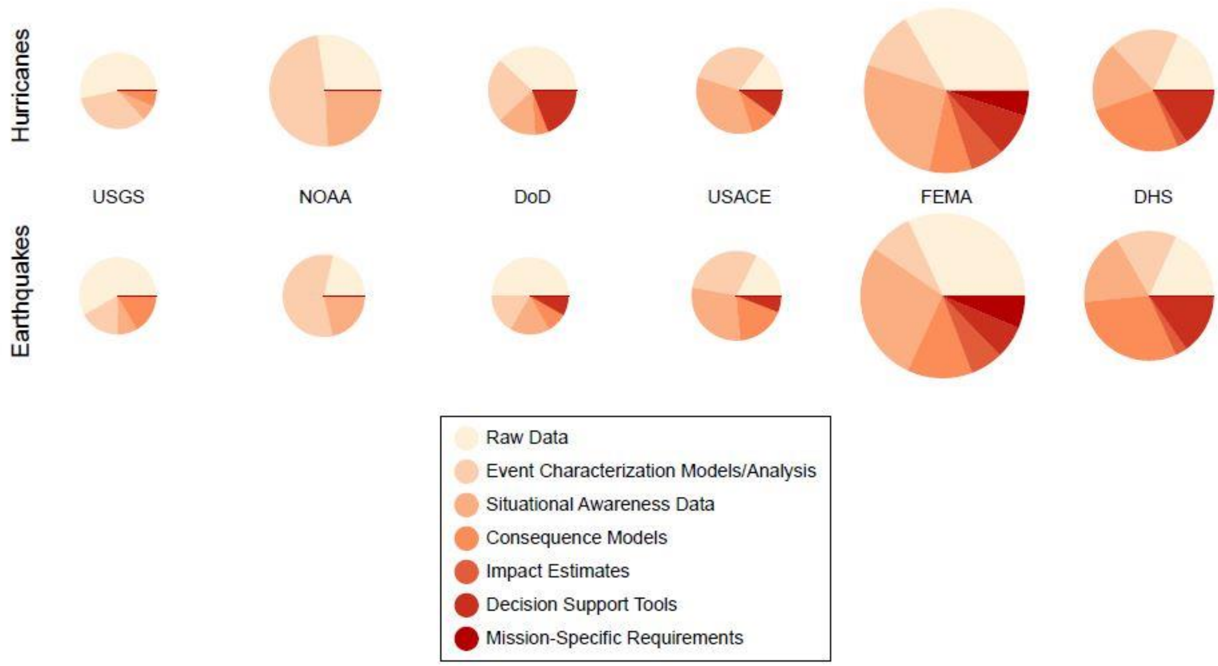


Figure 9. Top agency-level users of resources. The six organizations that use the largest number of resources are shown for both hurricanes and earthquakes. Each pie chart is sized relative to the total number of resources they use. The types resources used are shaded based on resource type. Organizations that use more raw data resources are located towards the left and organizations that use more decision support and mission-specific requirement resources are located towards the right.

Information coordination: Flow of information between resource owners

Summary

- Agencies that perform hazard-specific event analyses are the largest sources of information for each scenario type (e.g. NOAA for hurricanes and USGS for earthquakes.
- USACE, FEMA, DHS, and the national laboratories are the agencies that use the most data from other agencies as inputs to their own resources.
- Identifying the primary producers of information for specific events can inform interagency coordination efforts, including pre-scripted mission assignments, Memorandums of Understanding, or other plans for mission-specific information sharing.

Information sharing depends both on knowing who needs data and who provides data. Agencies can provide outputs from their resources and can receive data inputs from other resources. The number of outputs and inputs for each resource has been mapped to the agency-level resource owner and is graphed in Figures 10 and 11.

The results of this analysis highlight patterns in resource ownership across the interagency. NOAA (hurricanes, Figure 10) and USGS (earthquakes, Figure 11) are major producers of hazard-specific raw data and event characterization models. A broader range of agencies own more operationally-focused resources such as decision support tools. This result is not surprising, as these resources are designed to answer specific questions and are often created by the organizations that need them to address information requirements that are specific to each agency’s emergency management missions. USACE, FEMA, DHS, and the national laboratories own the largest number of operationally-focused resources. These organizations are well-connected with many inputs and outputs, suggesting they serve as important information coordinators.

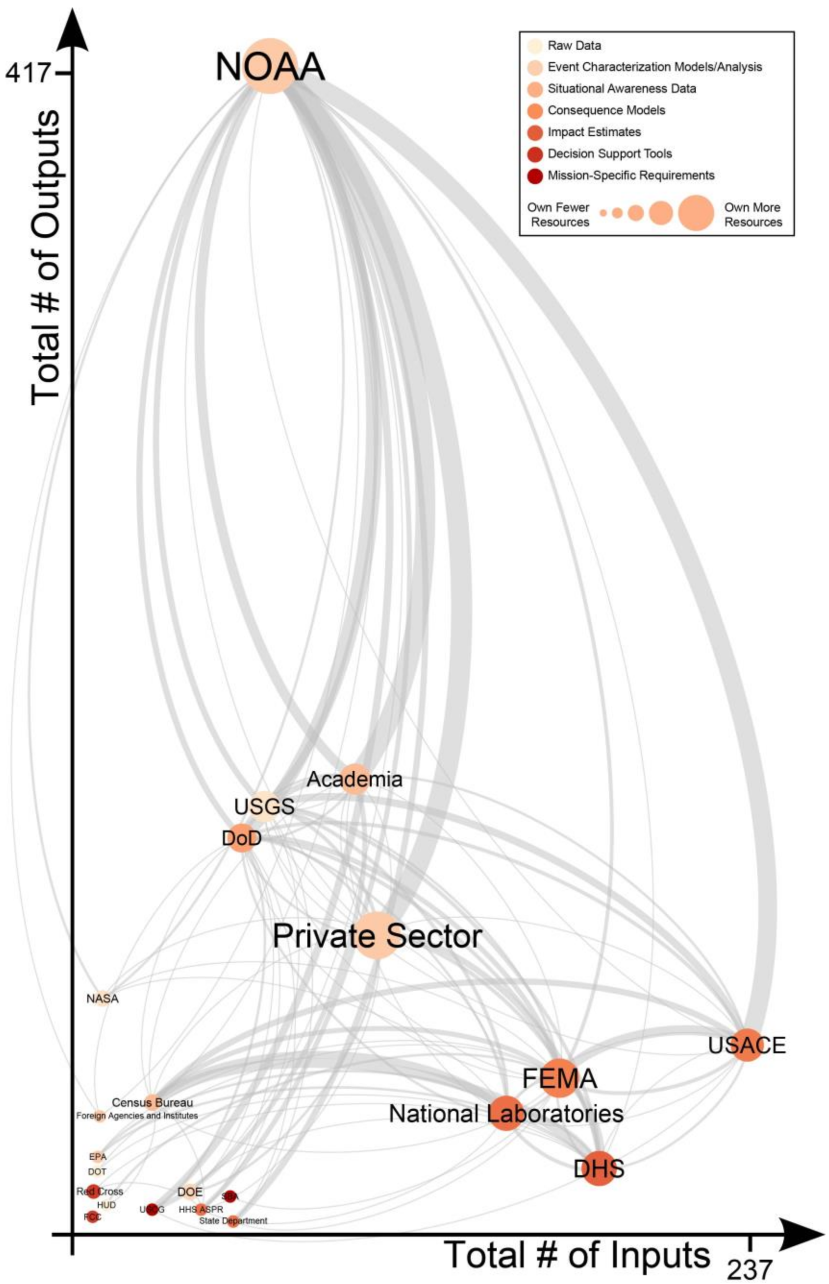


Figure 10. Information flow between agencies in the hurricane network. Each node (circle on the graph) represents an agency-level owner and is sized proportionally to the number of resources owned. Nodes are colored based on the average resource type of the resources owned by that organization. The organizations are graphed according to the total number of outputs and inputs for all the resources owned. Both direct and indirect connections were counted. Node locations were adjusted slightly in order to clearly display all organizations, and should not be interpreted absolutely but rather only relative to other nodes. Information moves clockwise, as shown by curved lines between nodes. The greatest number of outputs or inputs for any organization in the network is displayed on the respective axes.

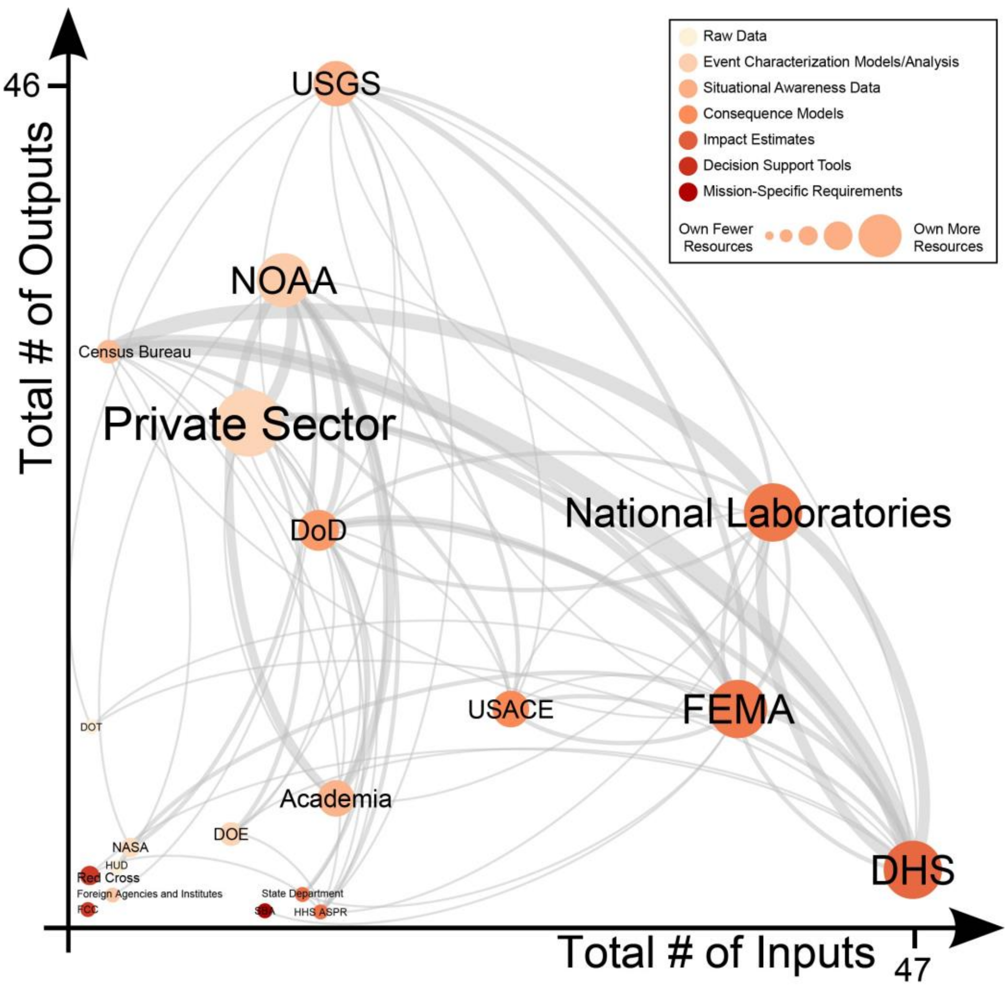


Figure 11. Information flow between agencies in the earthquake network. Each node (circle on the graph) represents an agency-level owner and is sized proportionally to the number of resources owned. Nodes are colored based on the average resource type of the resources owned by that organization. The organizations are graphed according to the total number of outputs and inputs for all the resources owned. Both direct and indirect connections were counted. Node locations were adjusted slightly in order to clearly display all organizations, and should not be interpreted absolutely but rather only relative to other nodes. Information moves clockwise, as shown by curved lines between nodes. The greatest number of outputs or inputs for any organization in the network is displayed on the respective axes.

Coordination with State and Local Partners

Summary

- The flow of information and phases of disaster management affecting state and local emergency managers correspond to those at the federal level.
- Efficient allocation of resources is the primary concern for state and local emergency management.
- State and local emergency managers often require a higher resolution of information than what is currently available for the federal level, specific to their region.

Emergency management is largely driven by those at the state and local level. To ensure that the results of this project incorporated their requirements and information resources, a number of stakeholders at the local, state, and regional levels have been interviewed. These interviews have focused on conversations with state emergency managers and a small number of additional contacts who have provided an overview of how data and modeling are used to support decision making during emergencies at the state and local level (see Appendix 7 for a list of interviewees).

Because each state has its own emergency management structure, the findings may not capture the entirety of the methods used by each state and likely oversimplify the differences between states and localities. The adage that “every emergency is a local emergency” applies, and the ways in which emergencies are managed differ widely. For example, this analysis compiles information collected from states with either centralized or home-rule emergency management and with widely varied emergency management capabilities. Therefore, this discussion serves solely as an initial assessment and generalization of the ways in which data and modeling resources are used and how state and local governments fit into the larger framework of national-level emergency management.

The mission of greatest concern to those at the state and local levels involved in emergency management is to efficiently and effectively allocate resources during response and recovery. These groups focus their efforts on collecting information regarding what assistance is needed and what resources are available. Some of this information may be collected in the planning phase, when outputs from federal models are used to predict the level and type of resources likely to be needed. Some states have developed their own tools to analyze the model outputs and provide these estimates. Once the event occurs, however, the majority of data-related efforts from the state and local agencies are in collecting assessment data to monitor and direct response activities.

The progression of emergency management activities for state and local emergency managers includes planning and preparedness, response, recovery, and mitigation, as it does at the federal level. Likewise, the flow of information, from raw data through mission-specific requirements, remains the same. The primary difference is in whether the state and local entities are using or producing that information. The upstream data, including outputs from event characterization models and consequence models, primarily come from the federal agencies that produce them. These data are provided by the lead federal agency for the information that produces and publishes official model outputs, from which the state and local consumers of the information either pull the data themselves or receive it, “pushed,” from the federal agency. In this way, states are operating on the basis of the same information that the federal government is. State emergency managers rely heavily on the data and model outputs produced by the federal government, and these data are generally shared effectively and in a timely fashion.

According to the interviewees, while the available data are at sufficient resolution for planning at the federal level, the requirements for accuracy and resolution are much higher for state and local planning and response departments, and those needs are not always met by the resources provided by the federal government. In many cases, these resources are still used, for lack of better alternatives, but others are not. For example, many states use the consequence outputs from HAZUS. Often, they use the runs performed and published by FEMA, but these are not well-suited for state and local use because of issues with resolution, accuracy, and timeliness of the data. Other states use HAZUS outputs generated through independent runs of the model using customized datasets. These datasets have been created to provide a more accurate representation of the local conditions (including soil type and facility locations) than what accompanies the standard HAZUS release. Of note, the forecasts generated by the National Hurricane Center were repeatedly described as being heavily used and useful. The predictions of location and severity of a hurricane at landfall are used invariably by state and county emergency response agencies, and the information provided is accurate and timely.

The critical infrastructure data made available through the Homeland Security Infrastructure Program (HSIP) also has several issues that prevent it from being used effectively by state and local emergency managers. Most of these problems arise due to inaccuracies in the geo-tagging of local resources in the federal-level maps. Also, because of the federal bias within the dataset, many of the facilities of importance to local officials are not included. In addition, once the emergency is over, states often lose access to HSIP Gold and cannot use it for planning or mitigation activities. Some states have begun addressing these gaps by compiling more detailed and locally-relevant critical infrastructure data sets of their own, but others are hopeful that this issue can be addressed at the federal level. Should designing a system intended for use by states and localities be undertaken, close collaboration between these entities and federal agencies would be necessary.

State and local entities contribute a larger percentage of the data for mission-specific activities than for event characterization. The primary responsibility of states and localities during response to an emergency is to efficiently and effectively allocate resources, including police, fire, and rescue crews. Tracking the availability of these resources is a major local issue. In order to support these missions, real-time assessment data regarding, for example, the status of critical infrastructure elements, power availability, and traffic flow, are critical. These data, when available, are usually collected by the service providers (e.g. DOT, power companies) and provided through collaboration with emergency management offices. However, access to these data is often lacking for states and localities; in some cases, this information is not available (not collected), and in others, it is collected by a number of entities and not shared effectively, if at all, with emergency officials. These data sets are critical to managing an effective response, but most states are not in a position to use them to their full potential. Structured management systems such as WebEOC generally have not been found useful to state emergency managers, partly because they are not used frequently enough. While efforts are beginning at the federal level to aggregate some of these data (e.g. the Department of Energy's EAGLE-I), it remains a gap, and one that will require cooperation with states, localities, and the private sector to be sufficiently addressed.

Discussion

Networks rely on a few highly central resources

Although data and models are used widely across the federal interagency, only a few resources stand out as being heavily used for both hurricane and earthquake scenarios (Table 1). In most cases, these widely used resources, such as HAZUS and SLOSH, are also the most central (Figures 9 and 10). These resources not only connect directly to a large number of upstream and downstream resources, but also connect to other highly central resources, like NHC Forecasts and HSIP, making them critical information bridges within the network. This observation highlights the importance of investments to maintain and update these resources to ensure the long term viability of this information system.

Additionally, the diversity of the user community involved in emergency management also highlights the importance of stakeholder engagement when considering maintenance, long term development strategies, and access requirements. Unilateral decisions regarding upkeep and future investments for these widely-used and central resources by the owner or funding agency may not take into account the needs of other users and stakeholders. Conversely, stakeholders need to invest in resources they use to ensure that those resources remain available.

Interagency coordination for resource development and maintenance

Interagency coordination specifically focused on developing and maintaining critical resources for the emergency management community has been successful in some well-established cases. The Homeland Security Infrastructure Program (HSIP) is one example of a resource developed and maintained by an interagency group specifically designed to address this coordination challenge. HAZUS is a highly central and widely-used resource that will require robust interagency support to ensure that it or its replacement remains an integral part of the network.

HSIP

HSIP is managed by an interagency working group led by DHS and the NGA that collates a large number of datasets from a wide range of public and private sources (586 data layers when last updated) into a single mapping platform and distributes the compiled product according to access requirements approved by the group. This coordination of efforts is time-intensive, but has generated one of the most widely used and frequently cited resources throughout the interagency. The success of HSIP and other resources managed and supported by interagency groups suggest that this mechanism could be a successful path forward to ensure the ongoing maintenance and stakeholder engagement with other critical resources within the information network.

Maintenance of HAZUS

HAZUS is a consequence model that has been used heavily across the federal interagency and at the state and local levels. The tool was designed for the Mitigation Division at FEMA as a loss estimation tool to gauge the scope of the financial burden of a specific event. The tool calculates, among others, economic loss (e.g., lost jobs and business interruptions), damage to infrastructure, and debris accumulation. However, HAZUS is now being used throughout the interagency as a tool to estimate consequences of earthquakes, hurricanes, and floods for a wide array of mission areas and as a source of data for other models beyond its original intent. HAZUS draws from several shared national databases, and some interagency users have developed methods to extend the use of HAZUS outputs to estimate additional impacts, such as temporary housing resource needs, affected populations, and personnel requirements. Understanding this expansion in utility of HAZUS is important, as it suggests that the model serves as an important backbone for operational decision making during emergency management.

Although widely used and highly central to network of resources analyzed in this study, HAZUS has been described as no longer a state-of-the-art model and is currently undergoing a re-tooling as part of a modernization effort. However, while the model has previously only been financially supported by FEMA, it, like other widely-used resources, should be updated and maintained with interagency support on the basis of its central role in supporting emergency management across the federal government.

Not all resources are well-connected

Network analysis of the hurricane and earthquake networks has identified a number of resources that are completely unlinked, neither providing information to nor receiving information from other resource network. In addition, some widely-used resources have limited connections to other resources, suggesting that the information from these resources could be better integrated. More robust linkages will ensure that the information generated is used efficiently and integrated effectively by decision makers during all phases of emergency management.

Orphan Resources

As shown in Figures 4 and 5 and listed in Table 2, about 15% of hurricane resources, and 18% of earthquake resources in the inventory are completely unconnected. These resources do not receive any information, nor are the outputs further processed or analyzed by other resources. If these resources remain unconnected to other resources, then the flow of information is severed, resulting in an incomplete picture of the event as a whole, and what needs to be done to respond effectively. For example, LSCMS (Logistics Supply Chain Management System) is a tool owned and used by FEMA to track resources required in the initial resource push to an affected region. LSCMS can also be used to project when more supplies will be needed. However, LSCMS is an orphan resource, suggesting that the data it provides are based on a series of assumptions not aligned with the event-specific data provided by upstream event characterization or consequence models, despite their availability. The incorporation of these upstream data is particularly important when the decisions made need to be coordinated with other groups within the same agency, ESF, or between ESFs. This coordination is critical to prevent conflicts caused by competing assumptions inherent in resource requirements calculations. Incorporating validated hazard-specific inputs helps ensure that downstream resources are processing information based on the most accurate, up-to-date data.

Widely-used resources with limited connections

Widely-used resources are expected to be central and well-integrated into the network; however, both the hurricane and earthquake networks contain resources that are widely-used, but poorly linked to the rest of the network. For example, EAGLE-I is one of the most widely-used resources in the inventory, yet has few linkages to other resources and is not well-integrated into the network (Figure 4 and 5).

When widely-used resources are not well-linked, this disrupts the flow of information, and results in the resource not being leveraged to its full potential. Therefore, just as improving linkages to orphan resources improves the functionality of the entire network, so does better integrating these widely-used resources help prevent gaps in the flow of information and ensures maximum availability and usage of information produced by these resources.

Redundancies

Analysis of the resources in both earthquake and hurricane networks reveals that few redundancies exist between resources used by the interagency, with most resources serving a unique function. However, there are eight situational awareness viewers in the inventory that all serve a similar function and are used for the same purpose (see Table 12 for a list of these resources). Each of the eight is owned by a different organization, of which four are only used by the organization that owns them.

Situational awareness viewers are typically map-based platforms that provide event-specific information overlaid with steady state data, including infrastructure and population data. With the exception of EAGLE-I, which is the most heavily used resource, the other six viewers have a limited number of federal users. FEMA GeoPlatform and OnTheMap for Emergency Management are the only two that are publicly accessible; all other viewers have limited access, either to their own employees (e.g. SIMON and SimSuite, which are only available to State and DoD, respectively) or to a limited subset of the emergency management community.

Situational awareness viewers are critical resources for emergency managers and are heavily used within each agency (many users within the agency, as opposed to widely-used between different agencies). A comprehensive situational awareness platform that uses a common set of validated data layers and models and made available to the federal interagency would significantly improve information sharing within and between ESFs. Such sharing of information and the validation of data layers used in multiple situational viewers is critical to providing a complete, shared understanding of the event upon which to make coordinated decisions regarding preparedness and response operations.

Table 12. Situational awareness viewers across the federal interagency. The situational awareness viewers are listed alphabetically, along with their owners, users and a short description.

Resources	Owners	Users	Description
EAGLE-I	DOE	DHS, DoD, DOE, FEMA, HHS ASPR, NOAA, USACE, USCG, USDA, White House NSC	Aggregates, processes, and displays near real-time feeds covering the nation's electric grid.
FASTMAP	DHS; Sandia	DHS	Browses and analyzes national infrastructure and emergency resource data.
FEMA GeoPlatform	FEMA	FEMA	Provides access to emergency management-relevant geospatial data.
MedMap	HHS ASPR	HHS ASPR, DHS, DoD	Maps infrastructure locations and facility/demographic data against hazard imagery.
OnTheMap for Emergency Management	Census	FEMA, Red Cross, DOE	Summarizes worker data for reported disaster zones or user-defined areas.
SIMON	State	State	Maps critical infrastructure against hazard data for risk assessment.
SAGE	DoD	DoD	Collects and distributes geospatial data for natural disasters, nuclear threats, or any other hazards, and can locate desired personnel through SAGE's Blueforce tracking devices.
SimSuite	USACE	USACE, FEMA, USGS, DoD	Provides multi-hazards modeling and data viewing for planning, response, and recovery.
IMT	DHS	DHS	Provides detailed infrastructure data to be viewed in the context of other data layers such as energy and finance

Gap Analysis

Based on the results of the network and metadata analysis of the hurricane and earthquake resource inventories and information from interviews with subject matter experts, emergency managers, and senior level decision makers, a series of gaps in how the interagency uses information resources to support decision making during emergency management have been identified. Importantly, these are broad systems-level gaps that impact the entire federal interagency and the emergency management community; addressing these systems-level gaps will improve the flow of information that supports operational decision making during emergency management.

Every gap described below speaks to an overarching need to translate and link the outputs from existing data and modeling resources to response activities in order to support data-driven decision making across emergency management missions. Although robust tools to characterize hurricanes and earthquakes are widely used, network analysis reveals that information from event characterization and consequence models are not well-linked to resources that inform operational decision-making, including decision support tools and mission specific requirements.

Analysis of the network and metadata characteristics has revealed three major gaps that impede the translation of data and models to response activities. These gaps and Courses of Action to address them are described below.

Lack of operations-focused data, models, and analysis tools

The results described in this report suggest that there are few resources that provide operations-focused information and those resources that are used (including impact estimates, decision support tools, and mission specific requirements) are not sufficiently linked to connected to other resources. In particular, these resources do not sufficiently incorporate event-specific data, including either event characterization or consequence modeling.

Lack of cross-sector impact estimates

Impact estimates define the consequences of an event to both infrastructure and population. These data are needed to inform nearly all response and recovery operations, as well as informing planning efforts. Metadata analyses show that a total of nine impact estimate resources are used for hurricane and earthquake scenarios – less than 7% of the total number of resources in the inventories (Figure 15). A closer analysis of these resources confirms that there is no single cross-sector impact estimate resource available to provide the information needed by all ESFs and associated missions across the US.[5]

[5] For example, the Coastal Flood Loss Atlas provides access to a library of HAZUS runs, a cross-sector consequence model across the continental Eastern seaboard (Texas to Maine). However, this tool is limited to coastal flooding events and is primarily focused on hurricane events.

To ensure a robust response, a wide range of impact estimate data relevant to all mission areas need to be generated to inform decisions such as what resources need to be deployed where. In order to generate viable cross-sector impact estimates, the consequences to each sector and the impact on other sectors needs to be assessed. A robust cross-sector analysis will provide the entire operating picture, which the emergency management community can then use to respond effectively and efficiently.

Lack of impact estimate libraries

Impact estimates include outputs of predictive consequence models, historical consequence assessments, and real-time post-event assessment data. However, there are currently very few repositories for this type of data, and the existing repositories do not provide ready access to the data. For example, of the nine impact estimate resources that are available for earthquakes and hurricanes, only one is an impact estimate library, the Coastal Flood Loss Atlas (CFLA), which is used to inform decisions during pre-event planning or in the early hours after an event prior to when HAZUS runs become available approximately six hours post-event.

Impact estimate libraries are important tools for both planning and response efforts for senior level decision makers and those involved in operations. Immediately after an event, libraries containing the outputs from previous authoritative runs of consequence models, combined with historical data from similar events, provide information about the effects of a wide range of event scenarios can be used to inform early decisions when little or no assessment data are available. These data are particularly critical early in the response before the outputs of consequence models based on the current event have been produced or made available.

Many of the most robust and widely-used consequence models, such as HAZUS, require significant time and subject matter expertise to perform runs with the appropriate parameter inputs and then analyze the outputs. Impact estimate libraries are the only mechanism for those who do not have the expertise, computing power, or time to run the consequence models themselves to gain access to high resolution impact estimate data to feed decision support tools or inform decision making. An easily-accessible library of authoritative runs could be referenced for future planning or response operations. A searchable library of impact estimates would provide decision makers with data for historical comparison and inform critical early decisions during response, as well as make these data much more widely available for data-driven decision support throughout all phases of the emergency.

Very limited decision support tools and mission specific requirements available

Effective decision support tools and mission specific requirements translate authoritative information about an emergency into the actions that need to be taken to support response operations. These resources can estimate evacuation times for an impending hurricane (HURREVAC) or can estimate the amount of debris and the resources required to remove the debris (USACE Debris Estimating Model). The most effective tools, as described by interviewees, use mobile applications for the ready input of assessment data collected by those on the ground in the affected regions. This information can be collated into a centralized database from which the data is analyzed and provided back to those making operationally-relevant decisions. However, within the hurricane and earthquake inventories, there are very few resources available to the federal interagency, and because these resources are designed to fulfill requirements within only a narrow mission space, they are not available for all missions or ESFs.

Lack of connections to other resources in the network

Impact estimate and mission specific requirement data are poorly integrated in the network

Of the five available mission specific requirements in the inventory, four are orphans, unconnected to any other resources in the inventory. This lack of connections underscores a lack of integration and cohesiveness within the network. Connections to real-time event characterization data are critical to ensure that the resource requirements calculated by consequence models and decision support tools are data-driven and based on the same event-specific consequence data informing decisions across the ESFs. Regardless of whether new resources are developed to address the needs of each specific mission or whether the existing resources are expanded to provide information specific to a wider range of missions, all ESFs and missions should be supported by empirical data that is shared broadly within the interagency and available through effective mission specific requirements datasets.

Lack of response and recover models

Although cross-sector consequence models, such as HAZUS, are available and widely used for natural disasters, these models do not incorporate the effect of response dynamics on the predicted consequences. Incorporating response dynamics can significantly improve the value of the consequence models by identifying the key parameters of response and recovery. Identifying these parameters and the interdependencies between them would allow emergency planners and decision makers at all levels to understand the elements of an emergency as a whole and to be able to make informed decisions when prioritizing investments.

Of note, response modeling requires data that, although it might be available, have not been analyzed in the context of response dynamics. For events such as hurricanes, which are frequent and therefore well practiced, there are data available that could be leveraged to determine response times, the effect of first responder absenteeism, or the effect of traffic patterns on predicted evacuation routes. Models that incorporate such response parameters could be used to test assumptions and perform comparative analysis to evaluate which aspects of the response are most critical to reducing causalities or fatalities.

NIICHE-PRS is a hospital response model recently developed by NORTHCOM to begin addressing this gap. However, the model is narrowly focused on the public health response sector and does not address many of the other missions for which such modeling is needed.

Courses of action

The gaps identified as part of this analysis reflect a system that could be significantly improved by a few coordinated, systems-level investments. The Courses of Action below are focused on building a robust and well-connected network of resources that can provide the necessary information to those who need it when they need it in the context of emergency management.

Increase support for highly central resources within the network

- Update and maintain highly central resources through interagency investment
- Ensure the long-term viability of these highly-central and widely-used resources

Improve network integration

- Link and integrate orphan resources into the rest of the network
- Ensure that all widely-used resources are well connected to the network

Improve data sharing for situational awareness viewers

- Ensure that available situational awareness viewers pull from a common set of validated data layers and models
- Ensure that the emergency management community at all levels of the federal government has access to a common operating picture

Improve the flow of information within the network

- Ensure that the existing mission specific requirements datasets are integrated into the network
- Develop readily-accessible and searchable libraries of impact estimate data
- Identify the critical data requirements for all emergency support functions in order to develop relevant decision support tools and mission specific requirements that address these requirements
- Build decision support tools and mission specific requirements that support all emergency management missions

Next steps

The previous section outlines broad courses of action for the interagency to close gaps and improve the utility and robustness of the network of resources with the earthquake and hurricane inventories. In this section, concrete next steps are described to help address the gaps within the network and ensure that the hurricane and earthquake resource inventory is made available and is useful to the emergency management community.

Develop a concept of operations for the resource inventory

The overall goal of this project has been to identify and collate a list of the data and models used to inform operational decision making for emergency management. A concept of operations is needed to ensure that the inventory is incorporated into the day-to-day emergency management operations of each agency and ESF. Such a CONOPS will ensure that the inventory is used, maintained, updated, and included in planning documents so that the interagency can leverage the resources within it to support and inform decisions made during an emergency, whether during planning stages or during response and recovery activities.

Map resources to high resolution mission-specific data requirements

One of the major challenges remaining in emergency management is how to use the available resources to better inform decision making. Building the resource inventory and a user interface to access that information was a step forward. An in-depth analysis is needed for each ESF to map the existing resources to the data required for that mission both to ensure that the existing resources are identified and used, and gaps are clearly defined at a mission-specific level. Such an analysis would significantly improve the immediate utility of the inventory, help ensure that the information available in the inventory is applied effectively to the missions for which it was designed, and provide empirical evidence to support future investment decisions.

Develop impact estimate libraries

As identified in the gap analysis, very few repositories of impact estimate data are available to the emergency management community to support preparedness and response operations. A closer analysis of these few resources confirms that no single impact estimate resource covers a breadth of consequences, nor, when taken together, do they support the necessary ESF missions. A well-connected and well-functioning network of resources relevant to hurricanes and earthquakes relies on the availability of cross sector impact estimates. In order to ensure a robust, well-coordinated response, impact estimate libraries are needed to ensure that the outputs of the highly-central, widely-used consequence models are readily available to the broader emergency management community.

Develop decision support tools and mission specific requirements

Decision support tools and mission specific requirements serve the critical function of making event characterization and consequence data available to support operations-level decision making. Although several decision support tools and mission specific requirements are available to the federal interagency, these resources fulfill data requirements for only a narrow mission space. Developing tools to better support a broader range of emergency management missions would significantly improve the access of the operations community to the data they need to make informed decisions and ensure that those data are provided in a way that are immediately relevant and useful. Identifying and defining the data requirements from all ESFs would ensure that any new tools developed are meeting the needs of the operations community and ensure that those tools are effective and useful to the community for which they are designed.

Expand the inventory to additional hazards

The inventory presented in this report identifies data and modeling resources relevant hurricanes and earthquakes. As of this report, resources relevant to hurricanes, earthquakes, and INDs have been collated. To build a comprehensive inventory of data and modeling resources for emergency management, the effort would need to be expanded to additional scenarios. Of particular interest to those interviewed are biological and cybersecurity scenarios.

Biological scenarios, like cybersecurity scenarios, are likely to require fundamentally different response strategies than those scenarios previously addressed. Both events are caused by a largely invisible hazard and would require ongoing surveillance in order to identify and characterize the event. These event characteristics fundamentally change how information is used and when decisions need to be made on the basis of the available information. Expanding the resource inventory to include these additional scenarios would significantly expand the inventory, as there are few resources in the existing inventory that would be expected to directly support these other scenarios. For both biological and cyber events, it will be critical to determine what information is required, what resources are available, and how the existing resources will be used throughout all phases of emergency management.

Conclusions

Conclusions

- Data and/or modeling are used across the interagency and by those involved at all levels of emergency management.
- Producing operationally-relevant information requires iterative steps of data collection and processing.
- The data and models required for event characterization are largely available and widely used. Resources to effectively translate the consequences of those events into concrete response activities are needed for all ESF missions.

What is modeling?

When asked about what data and modeling they use, many people initially responded that they do not use models for operational decision making during emergency management. However, nearly all use data, and the vast majority have some type of data processing tool that helps to perform mission specific analysis of data collected over the course of their work prior to or during an emergency. While agencies such as NOAA and USGS require and use computationally intensive, highly complex models to produce the information they are tasked with providing, the majority of the tools used by the federal government to perform data analysis in support of response and recovery missions require, by necessity, only limited computing power and limited training. This difference suggests that the tools available are, at least in most cases, tailored to the needs of the users.

Iterative analysis

Data collection and analysis are iterative. There is a flow of information between each step of data collection and processing. As the modeling or data analysis becomes more operationally relevant, it becomes less computationally intensive. This progressive simplification and reduction is what allows those in the field to call up mission specific data analysis tools or input assessment data directly via their mobile devices and is also what limits the complexity of each single piece of information so that it can be processed by those who are responsible for tremendous breadth (e.g. the Federal Coordinating Officers and state and local emergency managers), as opposed to those responsible for tremendous depth (e.g. the meteorological scientists at NOAA).

This iteration of data collection and analysis has important implications for the tools themselves. While there was originally a perception that there are many redundant tools, these results suggest that, just as there are critical roles for both the meteorological scientists and the operational decision makers in emergency management, so too are there tailored roles for data collection and analysis tools. The key is that information can flow directly from one resource into another, that everyone who needs information at the same level of resolution or detail is able to share information with each other, and that when any one person needs access to information at a different level of resolution, that they know where to find that information.

This framework applies to state and locals as well as those in the federal government. Event characterization data are very often the same feeds that the federal government is producing. The states' major contribution is in providing decision support information—in the form of real-time assessment data—and mission specific requirements. Information from all sources (federal, state, and local) is shared in the same data stream. The extent to which the data come from the federal agencies versus the state and local entities vary by state. No matter the information balance, the key element in this relationship is the ability to easily share data in both directions. A standard, consistent mechanism to facilitate the sharing of information resources at the federal level would allow states to design their own systems that would integrate with the federal system.

Data translation for decision makers

Data and models are widely used across the federal interagency to support operational decision making for emergency management. The network of resources used for all phases of emergency management related to hurricane and earthquake scenarios is relatively mature and robust. Continued work to better integrate and coordinate sharing of the available data and outputs of the available computational models is critical to improve the effectiveness and efficiency of a federal response to an event. A few targeted investments based on the gaps identified in this analysis could increase the engagement of stakeholders from across the community and generate rapid and significant improvements. The identification and characterization of the used resources, as well as the systems-level analysis of how these resources function together to generate useful information, provides the basis to ensure that a response to any disaster is based on informed decision making and sets the stage for empirically-driven future investment. The final web-based inventory produced through this effort provides unique access to this information and will help ensure that the resources available are used ever more broadly to better inform emergency management decision across the federal interagency.

Appendix 1: The ESFLG Modeling and Data Working Group (MDWG) CHARTER

1.0 PURPOSE

This charter provides the framework for the establishment and structure of the Modeling and Data Working Group (MDWG). The MDWG is comprised of Emergency Support Function Leadership Group (ESFLG) members or designees and chaired by the Director of FEMA's Planning Division, Response Directorate. The MDWG will:

- Analyze the catastrophic scenarios to be addressed and prioritized;
- Define and assess information requirements for response planning and operational decision making;
- Evaluate existing modeling resources to support the range of scenarios and determine modeling input and output requirements;
- Identify gaps and recommend solutions to meet the modeling input and output requirements.

2.0 MISSION

The MDWG mission is to identify consistent, reliable, authoritative models and data sets for response planning and operational decision making for catastrophic events.

3.0 BACKGROUND

Scientific based models and empirical information products and programs are increasingly used to predict the effects of and inform response planning and operations, particularly when faced with complex, cascading "maximum of maximums" threats and incidents. These models and programs enable decision makers with enhanced situational awareness and heightened visualization of the operational environment to prepare and assess the response to catastrophic events. For example, the benefits of prompt and accurate modeling include improved incident warning, reduction of public anxiety through effective risk communications, and delineation of hazard areas. Both real world events and exercises alike have highlighted a need to standardize these processes and products. However, currently no central mechanism exists to address the doctrine, organizational, training, materiel and leadership requirements necessary to exploit the effective use and coordination of such models and products.

The lack of a formal and standardized approach to integrating scientific modeling and coordinating related technical programs is a challenge to information sharing as well as to the development of effective preparedness plans and responses. The need to develop a standardized framework of modeling across the Emergency Support Function Leadership Group (ESFLG) structure is essential to closing core capability gaps, and improving the overall effectiveness of models for both planning and operations. The MDWG will address modeling and analysis requirements and the most effective ways to exploit emerging data generation products, to include scientific modeling and data sets to meet those requirements.

4.0 MEMBERSHIP

The Modeling and Data Working Group (MDWG) members were nominated by the Emergency Support Function Leadership Group (ESFLG) and will meet on a monthly basis. A list of the voting organizations of the MDWG is attached. The MDWG will address the most effective ways to exploit emerging data generation products, to include scientific modeling and data sets. The working group will determine the most effective programs to incorporate into the ESFLG structure as well as to evaluate implementation success.

5.0 ROLES AND RESPONSIBILITIES

- The MDWG voting members will provide primary and alternate representatives to contribute throughout the process.
- Each primary organization of the MDWG will have a voting responsibility when dealing with modeling and data issues that affect the interagency working group.
- The MDWG gathers and assesses modeling and information requirements for catastrophic scenarios and will provide regular updates to the ESFLG for evaluation.
- The ESFLG will then use the information compiled to work with the Office of Science and Technology Policy (OSTP) and the National Security Staff (NSS) to develop and formalize interagency modeling capability governance and coordination.

6.0 DELIVERABLES

The working group will provide an update status to the ESFLG on a monthly basis.

The working group will provide the following deliverables:

1. Identify and analyze the catastrophic scenarios to be addressed and prioritized;
2. Define and assess information requirements for response planning and operational decision making;
3. Define information requirements for response planning and operational decision making.
4. Develop criteria to evaluate and determine modeling and data source that support requirements
5. Evaluate authoritative modeling and data sources to support catastrophic scenarios; and
6. Identify gaps and recommend solutions to solve the identified modeling and information requirements.
7. Utilize the results from each scenario to inform subsequent scenarios.

7.0 RESOLUTION OF ISSUES AT MDWG MEETINGS

- The working group will utilize the ESFLG structure to resolve interagency coordination issues.

- Any interagency issues that cannot be resolved at the ESFLG level will consult the National Security Staff (NSS) and the Office of Science and Technology Policy (OSTP) for resolution of policy issues.
- Finalize resolution of policy issues will be handled by the Domestic Readiness Group (DRG).

8.0 ESFLG WORKING GROUPS

The MDWG is an ESFLG working group, in accordance with the ESFLG Charter. ESFLG working groups will include appropriate expertise and representation to guide the development of the requisite procedures for response and recovery activities under the National Response Framework (NRF) and National Disaster Recovery Framework (NDRF), as well as Federal Interagency and National planning efforts. Representation on working groups will be open to selected departments and agencies and FEMA Regions as appropriate.

The working group's purpose is to:

- Convene on an ad-hoc basis as designated for specific issues, and disband upon completion of the specific assigned task;
- Address issues that require appropriate department/agency participation for researching and developing procedures to operationalize and execute policy decisions;
- Identify and suggest process improvements to the ESFLG for approval;
- Provide input from subject matter experts; and
- Provide expertise to the Federal response community to address tasks including the research and development of potential options/courses of action and drafting of documents, recommendations, and procedures to improve Federal interagency coordination, integration, and incident response.

9.0 MDWG Primary Voting Organizations

Department of Agriculture

Department of Agriculture/Forest Service

Department of Commerce

- National Oceanic and Atmospheric Administration

Department of Defense (OSD, Joint Staff)

Department of Defense/U.S. Army Corps of Engineers

Department of Energy

Department of Energy/National Nuclear Security Administration

Department of Health and Human Services

Department of Homeland Security

- Federal Emergency Management Agency
- U.S. Coast Guard

Transportation Security Administration

Immigration and Customs Enforcement

Customs and Border Protection

United States Secret Service

Office of Science & Technology

United States Citizenship & Immigration Services

Department of Housing and Urban Development

Department of the Interior

Department of the Interior/National Park Service

Department of Justice

Department of Transportation

Environmental Protection Agency

Small Business Administration

Appendix 2: The ESFLG Modeling and Data Working Group Project Plan

DHS/FEMA

The ESFLG Modeling and Data Working Group (MDWG)

Project Plan

RD-Planning/ESFLG/MDWG/MDWG Project Plan.doc/svc
8/6/2012

Introduction

In July of 2012, both the Department of Homeland Security (DHS) and Federal Emergency Management Agency (FEMA) agreed that FEMA would coordinate the creation and implementation of an interagency Modeling and Scientific Workgroup (MDWG), with the full support and involvement of the Emergency Support Function Leadership Group (ESFLG). At the July 19, 2012 ESFLG meeting, there was concurrence by the ESFLG to form the Modeling and Data Working Group (MDWG) and designate a representative from their department/agency to participate on the MDWG. On July 31, 2012, the MDWG was formed from ESFLG nominations and the August 6th kickoff meeting was announced. The MDWG will assess the current state of modeling systems used, including their owners, requirements, consumers, production processes and means of public messaging. The working group will utilize the ESFLG structure to resolve routine interagency coordination issues. The working group will consult the National Security Staff (NSS) for resolution of policy issues. The purpose of the MDWG will be information gathering – regular updates will be provided to the ESFLG. The ESFLG will then use the information compiled to work with the NSS to develop and formalize interagency modeling capability governance and coordination.

Background

Scientific based models and data generation products and programs are increasingly used to predict the effects of and inform response planning and operations, particularly when faced with complex, cascading “maximum of maximums” incidents. These models and programs enable decision makers with enhanced situational awareness and heightened visualization of the operational environment to prepare and assess the response to catastrophic events. For example, the benefits of prompt and accurate modeling include improved incident warning, reduction of public anxiety through effective risk communications, and delineation of hazard areas. Both real world events and exercises alike have highlighted a need to standardize these products, programs, and processes. A need exists to understand the strengths and constraints of each scientific model and related technical program; enabling the closing of core capability gaps, however, currently no central mechanism exists to address the doctrine, organizational, training, materiel and leadership requirements necessary to exploit the effective use and coordination of such models and products.

The lack of a formal and standardized approach to integrating scientific modeling and coordinating related technical programs is a challenge to information sharing as well as to the development of effective preparedness plans and responses. The need to develop a standardized framework of modeling across the Emergency Support Function Leadership Group (ESFLG) structure is essential to closing core capability gaps, and improving the overall effectiveness of their use in both planning and operations.

Project Plan

The MDWG will address the most effective ways to exploit emerging data generation products, to include scientific modeling, data requirements, and geospatial analysis for catastrophic scenarios. The working group will determine the most effective modeling and data products to incorporate into the

ESFLG structure as well as to evaluate implementation success. Further, Presidential Policy Directive #8 (PPD-8), and specifically the response core capabilities, will inform this process and support this effort.

The MDWG will:

- Analyze catastrophic scenarios to be addressed;
- Assess data requirements for response planning and operational decision making;
- Evaluate existing resources to support scenarios and address data requirements;
- Identify gaps and recommend solutions to solve the data requirements.

Roles/Responsibilities

- The MDWG voting members will provide primary and alternate representatives to contribute throughout the process.
- Each primary organization of the MDWG will have a voting responsibility when dealing with modeling and data issues that affect the interagency.
- The MDWG gathers and assesses modeling and data requirements for catastrophic scenarios and will provide regular updates to the ESFLG for evaluation.
- The ESFLG will then use the information compiled to work with the OSTP and NSS to develop and formalize interagency modeling capability governance and coordination.

Project Management

1. The membership group will establish a charter.
2. The membership group will establish a work plan.
3. The MDWG will meet monthly to discuss working issues.
4. The MDWG Chair will provide an update to the ESFLG on a monthly basis.
5. The MDWG will provide a formal status update to the ESFLG annually.
6. The MDWG voting members will provide primary and alternate representatives to contribute throughout the process.

Deliverables

The MDWG will provide an update status to the ESFLG on a monthly basis.

The MDWG will provide the following deliverables:

1. Identify and analyze the catastrophic scenarios to be addressed and prioritized
    a. Review the 15 National Planning Scenarios
    b. Review other catastrophic scenarios (i.e. flooding, tsunami, solar storms)
    c. Prioritize scenarios and choose pilot scenarios
    d. Establish process and rating scheme for prioritizing scenarios
2. Define and assess data requirements for response planning and operational decision making
    a. Map the data requirements for the pilot scenarios

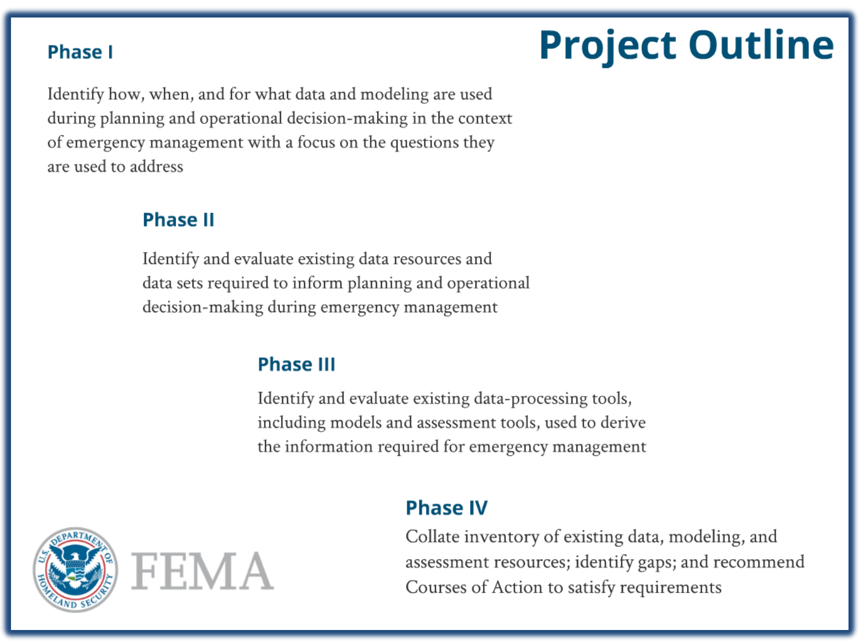
   b. Identify the response organizations for each pilot scenario
   c. Collect input from the response organizations on their current modeling and data requirements supporting these pilot scenarios
3. Evaluate authoritative modeling and data sources to support pilot catastrophic scenarios
   a. Review the modeling and data requirements of each response organization
   b. Define the lead agency responsible for the modeling and data products
   c. Identify the consumers of each modeling and data product
4. Identify gaps and recommend solutions to meet the identified modeling and data requirements
   a. Determine if the existing modeling and data products are meeting the needs of the response organizations and stakeholder groups (e.g. White House, Public, etc.) in assisting them to make informed decisions.
   b. Develop a matrix to determine gaps in modeling and data requirements for each pilot scenario
   c. The MDWG will vote upon solution sets for each gap identified and recommend these solutions to the ESFLG for review and approval
5. Utilize the results from the pilot scenarios to inform subsequent catastrophic scenarios
6. Provide a formal briefing to the ESFLG annually on work accomplished during the fiscal year.

Phase I Questionnaire

The MDWG Charter recognizes the need to “develop a standardized framework of modeling across the… [ESF] structure…” Informed by national preparedness goals and the associated core capabilities, this effort will produce an expansive list of modeling and data resources used during all stages of emergency activities. Based on the list generated through informed interviews with experts in each department, the MDWG will ultimately determine the most effective modeling and data products to incorporate into the ESFLG structure and evaluate implementation success. In addition to unifying modeling and data resources in use, this process will identify gaps in currently available modeling and data resources.
The MDWG will:

- **Analyze catastrophic scenarios to be addressed;**
- **Assess data requirements for emergency planning and operational decision making;**
- **Evaluate existing resources to support scenarios and address data requirements;**
- **Identify gaps and recommend solutions to satisfy the data requirements.**

The project will be separated into three phases. This questionnaire is phase I of the MDWG requirements analysis, designed to elicit both general and specific data requirements to inform phases II and III. It is intended for high-level Emergency Managers and Interagency Policy/Planners (Current MDWG group). This questionnaire focuses on two notional “use cases”, the Hurricane Ono scenario and the New Madrid Earthquake scenario; other scenarios will be added by exception. Collection of this information is focused on all hazards; notional disasters are used to elicit specific information where appropriate. Phases II and III will involve additional detail and levels of complexity by engaging SMEs with the goal of assessing the volume, velocity, and variety of modeling and data efforts for disaster preparedness, response, recovery, and mitigation. Data will be collated and provided in a report at the conclusion of each phase.



SECTION 1: PARTICIPANT AND AGENCY PROFILE

Last Name: **First Name:**

Phone Number (primary): **Phone Number (alternate):**

Fax: **Email Address:**

Work Address:

Home Organization:

Department, Division or Office Name:

Position Title:

1. **Are you considered a program manager, SME or both?**
2. **For which of the following Emergency Support Functions (ESF) does your division support and what is your role (Coordinator, Primary, Secondary)? Select all that apply**

___ ESF #1 – Transportation ___C ___ P ___ S

___ ESF #2 – Communications ___C ___ P ___ S

___ ESF #3 – Public Works and Engineering ___C ___ P ___ S

___ ESF #4 – Firefighting ___C ___ P ___ S

___ ESF #5 – Emergency Management ___C ___ P ___ S

___ ESF #6 – Mass Care, Housing and Human Services ___C ___ P ___ S

___ ESF #7 – Resource Support ___C ___ P ___ S

___ ESF #8 – Public Health and Medical Services ___C ___ P ___ S

___ ESF #9 – Urban Search and Rescue ___C ___ P ___ S

___ ESF #10 – Oil and Hazardous Materials Response ___C ___ P ___ S

___ ESF #11 – Agriculture and Natural Resources ___C ___ P ___ S

___ ESF #12 – Energy ___C ___ P ___ S

___ ESF #13 – Public Safety and Security ___C ___ P ___ S

___ ESF #14 – Long-term Community Recovery and Mitigation ___C ___ P ___ S

___ ESF #15 – External Affairs ___C ___ P ___ S

3. **For which of the following Recovery Support Functions (RSF) does your division support and what is your role (Coordinator, Primary, Secondary)? Select all that apply.**

___ Community Planning and Capacity Building ___C ___ P ___ S

___ Economic ___C ___ P ___ S

___ Health and Social Services ___C ___ P ___ S

___ Housing ___C ___ P ___ S

___ Infrastructure Systems ___C ___ P ___ S

___ Natural and Cultural Resources ___C ___ P ___ S

4. **For which of the following Mitigation Core Capabilities does your division support? Select all that apply.**

___ Hazard Identification

___ Long-term Vulnerability Assessment

___ Risk and Disaster Resilience Assessment

___ Community Resilience

5. **Please provide contact information for the lead modeling point of contact for your function so we can follow-up with them.**

6. **How does the use of modeling and empirical data add to your division's mission?**

7. **How does your division generally use modeling and the associated data sets required to support pre- and post-emergency activities?**

   a) **event preparedness?** *(e.g. risk assessments and threat hazard identification; estimating available capabilities and determining required capabilities)*

   b) **event mitigation?** *(e.g. identifying characteristics and potential consequences of hazards; identifying the benefit of risk reduction efforts)*

   c) **event response?** *(e.g. improving Situational Awareness; establishing response priorities)*

   d) **event recovery?** *(e.g. determining resource requirements; guiding restoration efforts)*

SECTION 2 - DATA REQUIREMENTS

1. **In a scenario such as Hurricane Ono:**

   a) **What data sets do you use to support your modeling efforts? On what types of data are your modeling parameters typically based?**

   b) **From what sources do you obtain the information and data required to support your division's responsibilities? Check all that apply**

   ___ Commercial database provider

   ___ Public Internet

   ___ Informal social network

   ___ In-house library/archive

   ___ Local Government (SPECIFY):

   ___ State Government (SPECIFY):

   ___ National Agency (SPECIFY):

   ___ Other (SPECIFY):

   c) **With whom do you collaborate in defining your data requirements and/or sources?**

2. **In a scenario such as the New Madrid Earthquake:**

   a) **What data sets do you use to support your modeling efforts? On what types of data are your modeling parameters typically based?**

   b) **From what sources do you obtain the information and data required to support your division's responsibilities? Check all that apply**

   ___ Commercial database provider

___ Public Internet

___ Informal social network

___ In-house library/archive

___ Local Government (SPECIFY):

___ State Government (SPECIFY):

___ National Agency (SPECIFY):

___ Other (SPECIFY):

c) With whom do you collaborate in defining your data requirements and/or sources?

SECTION 3 – MODELING APPLICATIONS

1. **How would modeling be used within your division specifically to support pre- and post-emergency activities in the event of a scenario such as Hurricane Ono?** *(e.g. aid in making pre-landfall evacuation decisions; determining required core capabilities and supporting resources)*

   a) **What specific models would you use?**

   b) **Which questions would these models be used to address?**

   c) **Is there an alternate model available that could be used to address these same questions?**

2. **How would modeling be used within your division to specifically to support pre- and post-emergency activities in the event of a scenario such the New Madrid earthquake?** *(e.g. aid in making post-event evacuation decisions; determining required core capabilities and supporting resources)*

   a) **What specific models would you use?**

   b) **Which questions would these models be used to address?**

   c) **Is there an alternate model available that could be used to address these same questions?**

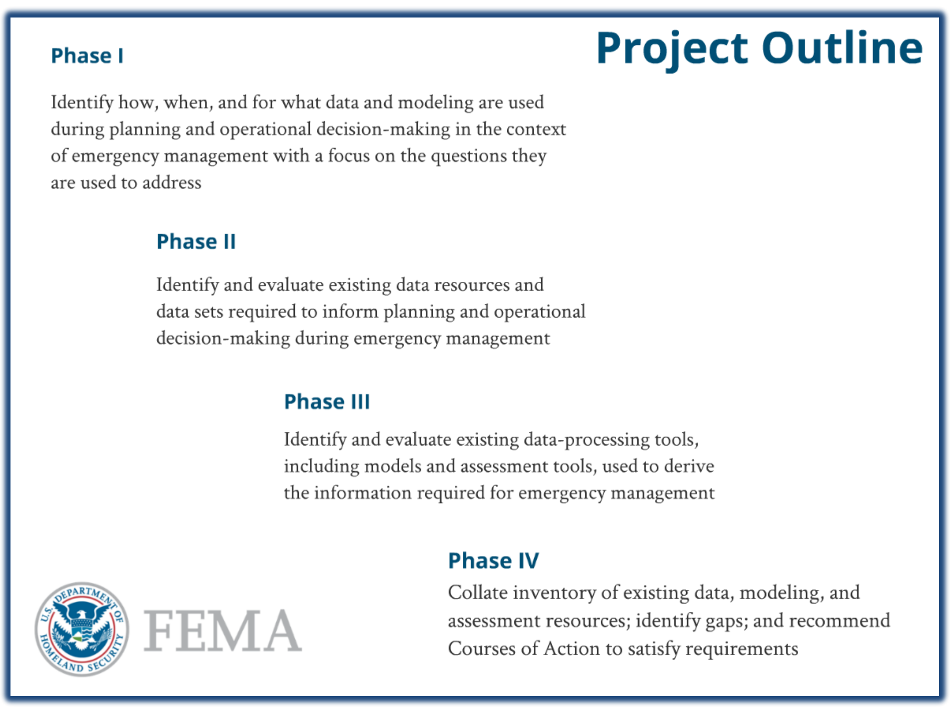
Phase II Questionnaire

The MDWG Charter recognizes the need to "develop a standardized framework of modeling across the… [ESF] structure…" Informed by Presidential Policy Directive #8 and the core capabilities, this effort will produce an expansive list of modeling and data resources used during all stages of emergency activities. Based on the list generated through informed interviews with experts in each department, the MDWG will ultimately determine the most effective modeling and data products to incorporate into the ESFLG structure and evaluate implementation success. In addition to unifying modeling and data resources in use, this process will identify gaps in currently available modeling and data resources.

The MDWG will:

- Analyze catastrophic scenarios to be addressed;
- Assess data requirements for response planning and operational decision-making;
- Evaluate existing resources to support scenarios and address data requirements;
- Identify gaps and recommend solutions to satisfy the data requirements.

The project will be separated into four phases. This questionnaire is associated with Phase II of the MDWG requirements analysis, designed to identify specific data resources available to address two "use cases", the Hurricane Ono scenario and the New Madrid Earthquake scenario; other scenarios will be added by exception. Phase III will involve additional detail and levels of complexity by engaging modeling SMEs with the goal of assessing the volume, velocity, and variety of modeling efforts for disaster preparedness, response, recovery, and mitigation. Data will be collated and provided in a report at the conclusion of each phase.



SECTION 1 - PARTICIPANT AND AGENCY PROFILE

Last Name:

First Name:

Phone Number (primary):

Phone Number (alternate):

Fax:

Email Address:

Work Address:

Home Organization:

Department, Division or Office Name:

Position Title:

SECTION 2 – INFORMATION REQUIREMENTS

What information is required for you to make the decisions you need to make during disaster management?

How do these information requirements differ between stages of disaster management (planning, preparedness, response, recovery, and mitigation)?

At what level of resolution do you need that information?

SECTION 3 - DATA SOURCES

From what sources do you primarily obtain the information and data required to support your agency's responsibilities? Check all that apply.

- ☐ Commercial database provider
- ☐ Public Internet
- ☐ In-house database
- ☐ Local Government (SPECIFY):
- ☐ State Government (SPECIFY):
- ☐ Federal Agency (SPECIFY):
- ☐ Other (SPECIFY)

SECTION 4 – SPECIFIC DATA RESOURCES

What data sources does your department, division, or agency own, maintain, and/or fund?

For each of these data sources, please identify:

GENERAL INFORMATION

A. Specific (or potential) use cases for the data in the context of Emergency Management

B. For which phases of Emergency Management is the data most useful?

C. How the data are collected (Survey? Instrumentation? Observation? Regulatory data?)

D. The owner of the data or database

E. The individual or group responsible for updating and maintaining the data

F. Contact information for the database manager or IT specialist (if applicable)

G. Any relevant security restrictions (Who has access to the data? How?)

MAINTENANCE AND UPDATE INFORMATION

H. Are the data updated in real-time for event response and recovery?

IF YES:

1. How are the data uploaded from the field to the database?

2. What are the delays associated with updating the real-time data?

IF NO:

1. How frequently is the data updated?

2. Who is responsible for updating the data?

I. What, if any, QA/QC practices are in place?

DATA COMPATIBILITY INFORMATION

J. Resolution of the data (Census tract? 1 km? Threat or event-specific characteristics?)

K. Exported data formats

USER INFORMATION

L. Do you know of any specific models that use the data as inputs?

1. If so, do you have any relevant contact information for the individuals responsible for running or maintaining that model?

M. Which agencies or divisions use these data to support their decision making process?

N. Which types of decisions could be made using these data?

ADDITIONAL INFORMATION

O. What are the specific strengths of this source of data?

P. What are the weaknesses of this source of data?

Q. How could the data or database be improved?

SECTION 5 - GAP IDENTIFICATION

What sources of data do not have access to when you need them, and why?

What resources or policies would be most helpful to improve the quality of the data you are already using or maintaining?

Which agencies or organizations would you like to collaborate with more effectively to address your data and information requirements?

What agencies, organizations, or individuals would you recommend as excellent providers of data or information? Are there specific best-practices you have found to be particularly useful?

Phase III Questionnaire

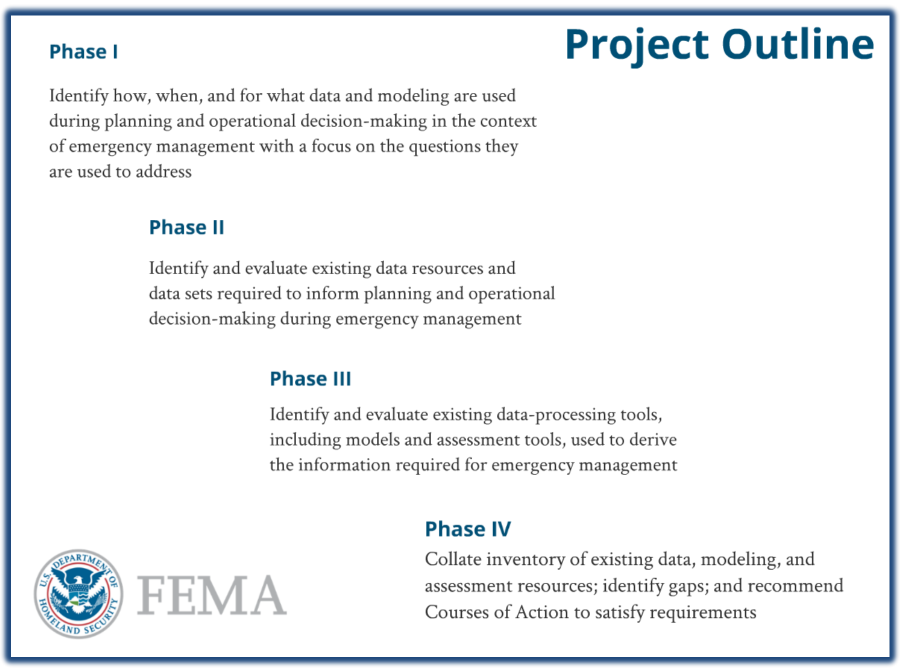
Project Overview

The Modeling and Data Working Group (MDWG) Charter recognizes the need to “develop a standardized framework of modeling across the… [ESF] structure…” Informed by Presidential Policy Directive #8 and the core capabilities, this effort will produce an expansive list of modeling tools and the data resources that underpin those models, categorized by their use in emergency management. This list of resources will be generated through informed interviews with experts in each department and agency represented on or recommended by the MDWG. Ultimately, the group will determine the most effective data and modeling products to incorporate into the ESFLG structure based on their utility across the interagency. Once the data and modeling resources in use have been identified, the gaps in available resources will be defined and courses of action proposed to fill those gaps.

The MDWG will:

- Analyze catastrophic scenarios to be addressed;
- Assess data requirements for response planning and operational decision making;
- Evaluate existing resources to support scenarios and address data requirements;
- Identify gaps and recommend solutions to satisfy the data requirements.

The project will be separated into four phases, as shown in the figure below. This questionnaire is associated with Phase III of the MDWG requirements analysis and is currently used to address the resources available to support operational decision making for emergency management of hurricane, earthquake, and improvised nuclear device scenarios. The goal of this phase of the project is to assess the models and data processing tools used for disaster preparedness, response, recovery, and mitigation. Data will be collated and provided in a report at the conclusion of each phase.



SECTION 1 – PARTICIPANT AND AGENCY PROFILE

Last Name:

First Name:

Phone Number (primary):

Phone Number (alternate):

Home Organization:

Position Title:

Department, Division or Office Name:

SECTION 2 – MODELS AND DATA ANALYSIS TOOLS USED

What models or data analysis tools do you use to support decision making during emergencies?

For each model or data analysis tool you mentioned above, please answer the following.

A. **For which phases of emergency management is the resource most useful to you (planning, preparedness, response, recovery, and/or mitigation)?**

B. **How do you use the resource to support decision making during emergencies?**

C. **Which individual or organization owns the rights to the resource?**

SECTION 3 – MODELS AND DATA ANALYSIS TOOLS OWNED

What models or data analysis tools does your department, division, or agency own, maintain, and/or fund?

3.1 GENERAL INFORMATION

For each model or data analysis tool you mentioned above, please answer the following:

A. **For which phases of emergency management is the resource designed to be used (planning, preparedness, response, recovery, and/or mitigation)?**

B. **During what emergency scenarios is the resource intended to be used?**

C. **Is the output of the resource freely accessible? How is it accessed (i.e. hosted online, downloaded, ordered)?**

D. **Is the resource itself freely accessible? How is it accessed (i.e. hosted online, downloaded, ordered)?**

E. **How frequently is the resource run (i.e. twice a day, once a month, immediately following an event)?** If this depends on the specific phase of emergency management (planning, preparedness, response, recovery, or mitigation) or other factors, please specify.

F. Who is responsible for producing runs or outputs from the resource? If this depends on the specific phase of emergency management (planning, preparedness, response, recovery, or mitigation) or other factors, please specify.

G. Who are the intended users? Who are the known users of the resource?

H. Who currently maintains the resource? How is it accessed?

3.2 TECHNICAL INFORMATION

For each model or data analysis tool you described in the previous section, please answer the following (to the best of your knowledge):

A. What are the inputs for the resource?

B. What are the outputs of the resource?

C. Are the outputs of the resource directly fed into any other models or data analysis tools (including your own)? If so, what are they?

D. In what file formats are the outputs available (i.e. Excel tables, shapefiles, KML files)?

E. What are the processing requirements for viewing the outputs of the resource (i.e. supercomputer, desktop/laptop, mobile device)?

F. What are the processing requirements for running the resource (i.e. supercomputer, desktop/laptop, mobile device)?

G. What is the approximate runtime of the resource (e.g. 4-6 hours on a supercomputer cluster)?

H. In what programming language (or on what platform) is the resource coded?

I. What is the current version of the resource and when was it released?

3.3 ADDITIONAL INFORMATION

For each model or data analysis tool you described in the previous section, please answer the following:

A. What are the specific strengths of the resource?

B. What are the limitations of the resource?

C. How could the resource be improved?

D. What additional data sources would improve the utility of the resource?

SECTION 4 – COMMENTS AND REFERRALS

Is there anything you would like to mention that was not addressed elsewhere in this questionnaire?

Is there anyone in your group or others that you would recommend that we interview for this study to refine our understanding of these resources and how they are used for emergency management?

Appendix 3: MDWG Membership

Name	Agency
Alt, Rich	DHS NPPD/IP (HITRAC)
Anderson, Debra	DHS S&T
Applegate, David	US Geological Survey
Artz, Richard	NOAA
Barrett, Todd	USDA Emergency Programs Division
Bausch, Doug	FEMA
Bennett, Gerilee	FEMA
Berman, Eric	FEMA
Billado, William	DHS IMAAC
Blumenthal, Daniel	DOE/NNSA
Blunt, Kenyetta	FEMA
Bonifas, Michelle	FEMA IA
Briggs, Kevin	NCS
Brown, Cliff	FEMA
Carroll, Shenan	FEMA
Chacko, Betsie	DHS IMAAC
Crawford, Sean	FEMA
Daigler, Donald	FEMA
Dial, Patrick	SBA
Dickinson, Tamara, Ph.D.	OSTP
Dozor, Josh	FEMA
Ewing, Melvin	FEMA

Flick, Darrin	DTRA
Franco, Crystal	DHS S&T
Gilmore, Lance	FEMA
Gleason, Joseph J CAPT	USCG
Gorman, Chad	FEMA
Griffith, David	FEMA NHC
Hammond, Steve	USGS
Hernandez, Patrick	FEMA
Hill, Laura	USDA USFS
Hinkson, Tasha	FEMA
Hodge, Craig	FEMA
Irwin, William	USACE
King, Steve	DHS
Knabb, Richard	NOAA
Landry, Mary	USCG
Lant, Tim, Dr.	HHS
Legary, Justin	FEMA
Leong, Timothy CIV	DTRA
Magnuson, Matthew	EPA
Mahrous, Karim	FEMA
Maycock, Brett	FEMA/Medical Liaison
McQueen, Jeff	NOAA
Monarez, Susan Dr.	DHS S&T
Montañez, José M. Gil	FEMA

Moore, Brian	USCG
Morgan, D'arcy	DHS S&T
Mueller, Lora	NOAA
Murray, Michelle	Department of State
Nye, William	USACE
O'Neill, Ed	Department of State
Olsen, Jennifer	HHS
Reeves, Toimu (Troy)	NORTHCOM
Remick, Alan	DOE/NNSA
Rhome, Jamie	NOAA
Roohr, Peter	NOAA
Sanderson, Bill	FEMA
Schilling, David	DOT
Scott, Margaret	DOE
Snead, Kathryn	EPA
Sokich, John	NOAA
Springstein, Thomas	FEMA
Tribble, Ahsha, Ph.D	NSS White House
Tune, Greg	Red Cross
Underwood, Patricia, PHD	DHS NPPD/IP (HITRAC)
ValentineDavis, Victor	DHS IMAAC
Valliere, John	SBA
Vaughan, Chris	FEMA
Villoch, Deborah	NPPD/IP

Wiacek, Chris	DOT

Appendix 4: Interviewees

NAME	AGENCY
Buikema, Ed	Argonne National Laboratory
Folga, Steve	Argonne National Laboratory
Gunn, Julia	Boston Public Health Commission
Demarais, John	CAP
St. John, Courtney	Columbia University, Center for Research on Environmental Decisions
Alexander, David	DHS
Billado, William	DHS
Briggs, Kevin	DHS
Chacko, Betsie	DHS
Cole, Ray	DHS
Coller Monarez, Susan	DHS
Cotter, Dan	DHS
Danielson, Glen	DHS
Franco, Crystal	DHS
Klucking, Sara	DHS
Langhelm, Ron	DHS
MacIntyre, Anthony	DHS
Mapar, Jalal	DHS
Maycock, Brett	DHS
Moe, Mathew	DHS
Shepherd, Dave	DHS
Valentine Davis, Victor	DHS
DeCroix, Michele	DHS
Berscheid, Alan	DHS NISAC/HITRAC
Chatfield, Catherine	DHS NISAC/HITRAC
Norman, Mike	DHS NISAC/HITRAC
Stamber, Kevin	DHS NISAC/HITRAC
Aeschelman, Jeremiah	DoD DTRA
Basiaga, Dariusz	DoD DTRA

Blandford, Michael	DoD DTRA
Blandford, Mike	DoD DTRA
Cooper, Charles	DoD DTRA
Grouse, Andy	DoD DTRA
Kahn, Todd	DoD DTRA
Leong, Timothy	DoD DTRA
Lowenstein, Eric	DoD DTRA
Mazzola, Tom	DoD DTRA
Meris, Ron	DoD DTRA
Phillips, Michael	DoD DTRA
Arenciaba, Janette	DoD NORTHCOM/NORAD
Baron, Thomas	DoD NORTHCOM/NORAD
Danaher, Leo	DoD NORTHCOM/NORAD
DeGoes, John	DoD NORTHCOM/NORAD
Friedman, Andy	DoD NORTHCOM/NORAD
Jackson, Mike	DoD NORTHCOM/NORAD
Limon, Salvador L	DoD NORTHCOM/NORAD
Wireman, Jody	DoD NORTHCOM/NORAD
Allen, Gary	DoD Office of the Secretary of Defense
Gerrig, Dan	DoD Office of the Secretary of Defense
Greenberg, Brandy	DoD Office of the Secretary of Defense
Miller, Brian	DoD Office of the Secretary of Defense
Mullen, Frank	DoD Office of the Secretary of Defense
Sorden, Caryn	DoD Office of the Secretary of Defense
Yu, Leigh	DoD Office of the Secretary of Defense
Blumenthal, Daniel	DoE
Cedres, Stewart	DoE
Clark, Jamie	DoE
Corredor, Carlos	DoE
Favret, Derek	DoE
Fernandez, Steve	DoE
Hsu, Simon	DoE

Lippert, Alice	DoE
Lucas, Anthony	DoE
Rollison, Eric	DoE
Scott, Margaret	DoE
Willging, Pat	DoE
Schilling, David	DoT
Stuckey, Bill	DoT
Vanness, Jeffrey	DoT
Howard, Jeffrey	Dun & Bradstreet
Clark, Steve	EPA
Haxton, Terra	EPA
Hudson, Scott	EPA
Irizarry, Gilberto	EPA
Lemieux, Paul	EPA
Magnuson, Matthew	EPA
Mosser, Jen	EPA
Snead, Kathryn	EPA
Woodyard, Josh	EPA
Tu, Julia	FCC
Almonor, Niclaos	FEMA
Anderson, Lindsey	FEMA
Bahamonde, Marty	FEMA
Bausch, Doug	FEMA
Bellamo, Doug	FEMA
Bennett, Gerilee	FEMA
Berman, Eric	FEMA
Bonifas, Michelle	FEMA
Boyce, Carla	FEMA
Brierly, Mick	FEMA
Brown, Cliff	FEMA
Crawford, Sean	FEMA
Daigler, Donald	FEMA

Decker, K.C.	FEMA
Demorat, David	FEMA
Ewing, Melvin	FEMA
Faison, Kendrick	FEMA
Farmer, Bob	FEMA
Gilmore, Lance	FEMA
Gorman, Chad	FEMA
Griffith, David	FEMA
Harned, Rebecca	FEMA
Hewgley, Carter	FEMA
Hinkson, Tasha	FEMA
Hodge, Craig	FEMA
Huyck, Charles	FEMA
Ingram, Deborah	FEMA
Jackson, Liz	FEMA
Jacques, Richard	FEMA
Juskie, John	FEMA
Kazil, Jacqueline	FEMA
Lawson, David	FEMA
Legary, Justin	FEMA
Longenecker, Gene	FEMA
Lumpkins, Donald	FEMA
McDonald, Blair	FEMA
Pollock, Marcus	FEMA
Preusse, Paul	FEMA
Rabin, John	FEMA
Ransom, Darrell	FEMA
Roberts, Nikki	FEMA
Rogers, James	FEMA
Rozelle, Jessee	FEMA
Sanderson, Bill	FEMA
Schlossman, Mikhail	FEMA

Scott, Kara	FEMA
Sonhaus, Daniel	FEMA
Stanfill, Derek	FEMA
Stuart, James	FEMA
Truax, Wayne	FEMA
Vaughan, Chris	FEMA
Wolfgul, Gus	FEMA
Woodhams, Katrina	FEMA
Wright, Roy E.	FEMA
Wycoff, Kristen	FEMA
Zohn, Ashley	FEMA
Zuzak, Casey	FEMA
Butgereit, Richard	Florida Division on Emergency Management
Baker, Jay	Florida State University
Gabriel, Edward	HHS ASPR
Koerner, John	HHS ASPR
Lant, Tim	HHS ASPR
Lurie, Dr. Nicole	HHS ASPR
Olsen, Jennifer	HHS ASPR
Shankman, Robert	HHS ASPR
Wright, Sue	HHS ASPR
George, David	JHU APL
Taylor, Steven	JHU APL
Waddell, Richard	JHU APL
Alai, Maureen	Lawrence Livermore National Laboratory
Buddemeier, Brooke	Lawrence Livermore National Laboratory
Goforth, John	Lawrence Livermore National Laboratory
Glascoe, Lee	Lawrence Livermore National Laboratory/NARAC
Homann, Steve	Lawrence Livermore National Laboratory/NARAC
Nasstrom, John	Lawrence Livermore National Laboratory/NARAC
Pobanz, Brenda	Lawrence Livermore National Laboratory/NARAC
Simpson, Matthew	Lawrence Livermore National Laboratory/NARAC

Sugiyama, Gayle	Lawrence Livermore National Laboratory/NARAC
Babb, William	Marton Technologies
Tuttle, Benjamin	NGA
White, Greg	NGA
DiMego, Geoff	NOAA
Draxler, Roland	NOAA
Feyen, Jesse	NOAA
Heffernan, Robyn	NOAA
Knabb, Richard	NOAA
Lapenta, Bill	NOAA
McQueen, Jeff	NOAA
Mitchell, Daisy	NOAA
Mongeon, Albert	NOAA
Roohr, Peter	NOAA
Sokich, John	NOAA
Tallapragada, Vijay	NOAA
Tolman, Hendrik	NOAA
Collins, Andy	Old Dominion University
Jordan, Craig	Old Dominion University
Myer, David	Old Dominion University
Robinson, Mike	Old Dominion University
Tune, Greg	Red Cross
Bynum, Leo	Sandia National Laboratories
John, Charles	Sandia National Laboratories
Jones, Dean	Sandia National Laboratories
Kimura, Margot	Sandia National Laboratories
Knowlton, Robert	Sandia National Laboratories
Kraus, Terry	Sandia National Laboratories
Mahrous, Karim	Sandia National Laboratories
Miller, Trisha	Sandia National Laboratories
Pennington, Heather	Sandia National Laboratories
Pless, Daniel	Sandia National Laboratories

Teclemariam, Nerayo	Sandia National Laboratories
Vurin, Eric	Sandia National Laboratories
Dial, Patrick	SBA
Valliere, John	SBA
O'Neill, Ed	State
Dowell, Earlene	US Census
Pitts, Robert	US Census
Diaz, Steve	USACE
Harris, Dewey	USACE
Hendricks, Joel	USACE
Irwin, Bill	USACE
Keown, Patrick	USACE
Markin, Chad	USACE
Nye, Bill	USACE
Schargorodski, Spencer	USACE
Schuster, Michael	USACE
Town, Patrick	USACE
Gleason, Joe	USCG
Gunning, Jason	USCG
Hunt, Michael	USCG
Landry, Mary	USCG
Lundgren, Scott	USCG
McGlynn, Matt	USCG
Moore, Brian	USCG
Carpenter, Ryan	USDA
Li, Yun	USDA
Collins, Brian	USFS
Erickson, Rod	USFS
Hill, Laura	USFS
Triplett, Sean	USFS
Applegate, David	USGS
Blanpied, Michael	USGS

Gallagher, Kevin	USGS
Haines, John	USGS
Hammond, Steve	USGS
Ludwig, Kris	USGS
Lyttle, Peter	USGS
Mandeville, Charles	USGS
Mason, Robert	USGS
Perry, Sue	USGS
Wald, Dave	USGS
Driggers, Richard	USGS

Appendix 5: Methods

The workflow of analysis performed for this project is divided into three parts: data collection, data processing, and analysis; this workflow is depicted in Figure A5.1 and described in brief in this section. See Appendix 5 for a complete description of the methods.

Data Collection

Data collection was performed through interviews with members of the MDWG, other emergency managers, and subject matter experts. In brief, the interviewees were asked how they use data and models to answer questions relevant to their emergency management mission, what data they use to address those questions, and what models or analysis tools they use to process those data. Based on the data collected during interviews, a systems-level analysis of the information requirements was conducted and an ontology, or categorization system, was developed to capture the flow of information between the resource types. The information ontology is described in detail in subsequent sections. Metadata about the specific resources identified during interviews as both operational and used by the federal emergency management community were compiled in an inventory. Metadata characteristics about each resource were defined both through interviews and through additional background research.

Each resource in the inventory is characterized by over twenty metadata tags, including information about the owners and federal users of the resource and the connections between resources. These metadata characteristics provided the basis for two types of analyses: a network analysis based on the upstream and downstream connections of each resource and a statistical analysis of the types of resources. The network analysis is based on network maps, visualizations of the resources and the flow of information between them. Analysis of the metadata characteristics of the resources was used to calculate the types and number of resources in the inventory. The Methods are described in detail in Appendix 5.

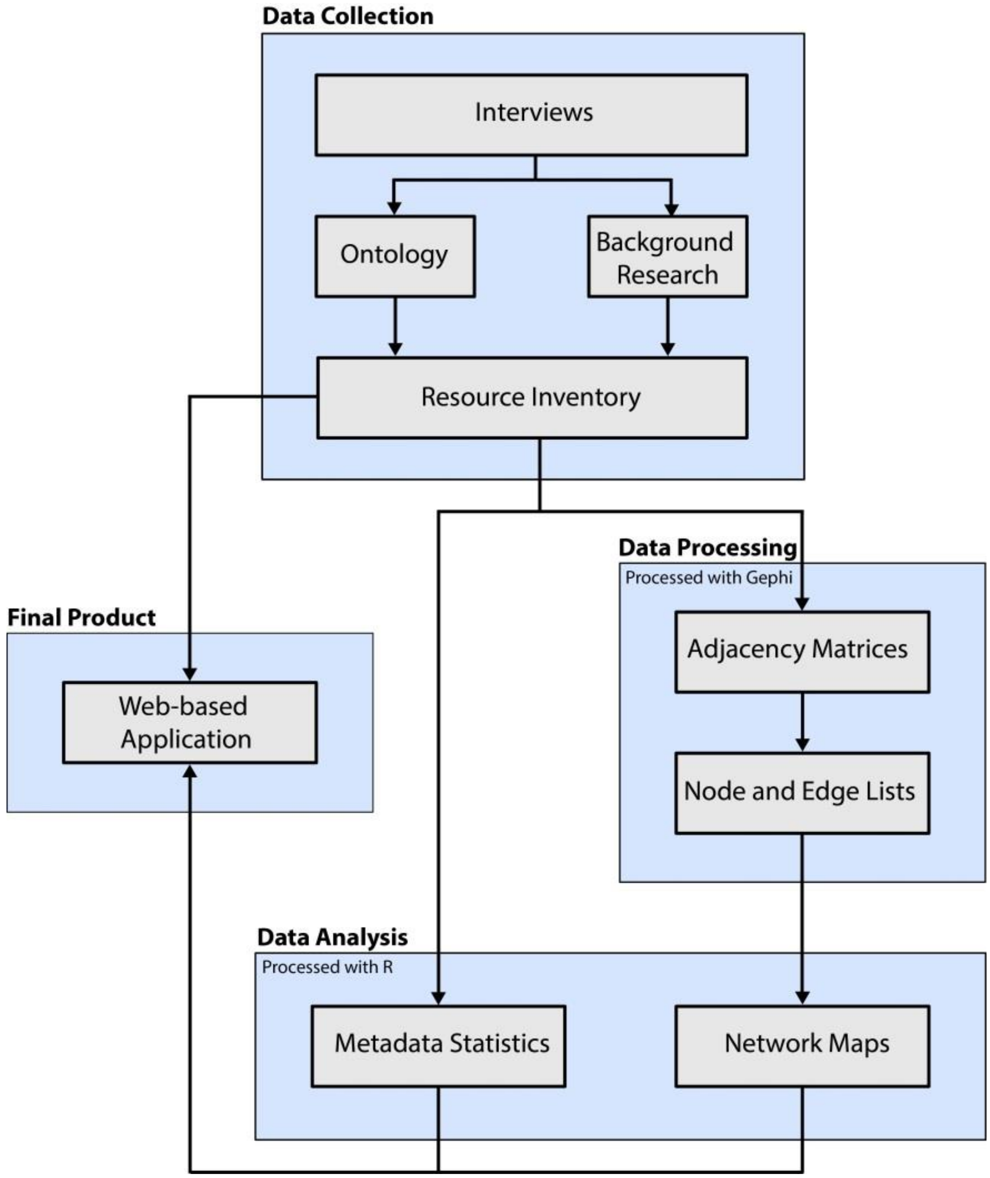


Figure A5.1. Analysis workflow. A depiction of the sequence of work involved in producing quantitative analysis of the resource inventory.

Interviews

The information required to analyze the available data and modeling resources was collected through a series of in-person and phone interviews with the members of the MDWG and the subject matter experts they recommended. During these interviews, the users and producers of each resource identified and characterized the ways in which each resource is used to support planning and operational decision making. In most cases, the MDWG members were interviewed initially. Interviews with additional subject matter experts or leadership were scheduled upon recommendation to provide further breadth or depth of information depending on the size of the agency or division represented and the expertise of each interviewee. In addition to federal officials, a number of state and local emergency managers were interviewed to assess their use of data and models in their respective agencies. Directors of state emergency management departments and other key personnel in their departments were interviewed based on the recommendations of MDWG members. The presidents of major associations of emergency managers (IAEM and NEMA) were also interviewed. Interview questions for state and local entities were similar to those for federal officials, with added emphasis on interaction with federal agencies.

During phase I, there was an emphasis on interviews with high-level decision-makers, program managers, and users of the data and modeling outputs, with a focus on how data and models are used to support operational decision making. The conversations focused on the role of each agency, division, or group during each phase of emergency management and the questions they use data and modeling to address during that work. During phase II, interviews were more targeted and were used to capture and categorize the technical details about an agency, division, or group's information requirements. During phases II and III, emphasis was placed on targeted interviews with subject matter experts who use, develop, or maintain data resources, analysis tools, and quantitative models. Informed by the results of phase I, phases II and III were more targeted efforts during which the technical characteristics of each resource were captured, characterized, and collated into an interactive library. In total, over 200 interviews were conducted with nearly 250 people representing 54 federal agencies, divisions, or groups. In addition, 10 interviews were completed with 15 individuals representing six states.

Interviews were opened with an introduction to the project. A questionnaire (see Appendix 2) was developed for each phase to outline the topics to be addressed during the interviews. These questionnaires were used as a general guide for the discussions. Throughout the project, interviewees have included those who are providers of data or are tool developers; those who are analysts and users of those data and tools; those who make operational decisions informed by data and modeling resources; and those who have roles that include a combination of tool-development, analysis, and decision making. Interviews are designed to capture an overview of the roles and responsibilities of each group and the ways in which data and data processing tools, including modeling, support those roles. The flow of the conversation varied widely based on the expertise of the interviewee and attempted to capture both the general and specific information requirements from each interviewee across the spectrum of emergency management missions and the phases of an emergency. A comprehensive list of the interviews completed can be found in Appendix 9.

Resource Inventory

A comprehensive inventory of resources used across the federal interagency and the linkages between them was generated on the basis of the resources discussed during interviews, followed by background research to identify inputs and outputs of each resource. Only resources with federal users were included in the inventory. Resources under development or not currently used to support emergency management activities were identified, but not included in the inventory. Information about these resources and how they function within the flow of information has been retained in an archived library. This information allows for more a more detailed analysis and verification of the analyses. Additionally, these resources can be used in future iterations of the report to suggest mechanisms to fill gaps identified in the current inventory. The inclusion of only used and operational resources in the inventory enables an analysis of how information currently travels within the interagency and results in a streamlined resource inventory containing the information immediately useful for emergency managers.

Metadata

The flow of information framework captures the functional, time-dependent, and mission-specific variation between resources used across the federal interagency. However, it does not describe other essential characteristics such as how those resources are accessed, used, and updated. These additional characteristics, or metadata, must also be collected to properly organize and analyze the resources to maximize effective usage during all phases of emergency management. These metadata will appear in the interactive inventory of resources upon completion of the project.

Metadata categories include: the resource's full name, abbreviation, model/data, owner, users, upstream resources, downstream resources, relevant hazards, core capabilities supported, emergency support functions (ESFs) supported, recovery support functions (RSFs) supported, key words, function tags, resource type, data collection method, phase specific utility, access information, access type, processing requirements, refresh rate, last known version, programming language, file type, contact information, contact during activation, website, and a brief summary of its function and use. Complete descriptions of each metadata tag are included in Appendix 6.

Data Processing

A network is defined as a system consisting of interconnected components where network analysis is the process of understanding the connections between those components. The individual components of the network are called nodes and the connections between them are called edges, with information moving through the network by a defined, or directed, flow. To build network maps describing the linkages between resources in the inventory, the metadata defining the upstream and downstream linkages for each resource was quantified in an adjacency matrix. An adjacency matrix is a mathematical method of representing a network that provides a simple way to calculate many network measures and statistics.[6] The adjacency matrix was then converted into separate node and edge lists. A node is a point on a network, and in this case, each node represents a single resource in the inventory. The nodes list contains the metadata of each node in the network, allowing that information to be visualized on the network map and analyzed in the context of the network. An edge is a line in the network that connects two nodes, and in this case, represents the transfer of information from one resource to another. The edge list contains a list of connections between nodes in the network. These node and edge lists were imported into Gephi,[7] an open source network visualization and analysis software, to create the network maps used in the analysis.

All data processing was performed using R, an open source, statistics-based programming language.[8] R was chosen because of its ease and efficiency in calculating basic and network-based statistics. An open source language, this coding language facilitates transfer of the analysis scripts to another party.

Data Analysis

Network Analysis

The analysis presented in this report describes the connections between the data and models used by the federal interagency in the context of emergency management. Two metadata categories (upstream and downstream resources) describe linkages between the resources based on the flow of information between those resources. These linkages were used to build a flow-based network of the datasets and models collated in the inventory. This dataset, including the resources and their associated metadata, and the network based on this dataset, was used to perform a preliminary analysis of the IND resource inventory, as described in the results section.

To visualize the data contained in the resource inventory, network maps were generated of the resources from their upstream and downstream metadata tags. In these networks, each dataset or model is a node in the network with each edge representing the flow of information and processing of data as it passes between those nodes. The size of a node and its label is directly proportional to the number of users of that resource, an indicator of the relative utility of each resource, which is defined by the number of federal agencies that directly use the resource in the context of their work.[9] The edges

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6 A short, rigorous definition of an adjacency matrix: For a network of n nodes, the adjacency matrix A is an n x n matrix where the i,j^{th} entry in the matrix represents the number of connections from the i^{th} node in the network, to the j^{th} node in the network.

7 Bastian M., Heymann S., Jacomy M. (2009). ***Gephi: an open source software for exploring and manipulating networks.*** International AAAI Conference on Weblogs and Social Media.

8 R Core Team (2013). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/

9 Note that users could also be calculated by including not only the number of direct users, but also those users of all resources that provide inputs for a given resources. We refer to this latter method as calculating "cumulative

curve in a clockwise fashion, distinguishing which resource is the source and which is the target of the information. In this case, the source node is the upstream resource. A downstream resource is defined as the one that the source node feeds. Figure A2 illustrates an example of a simple network map. Both the inputs (upstream resources) and outputs (downstream resources) of each resource in the network were identified based on in-depth analysis of interview data and a review of the technical documentation of the resource, when available.

Unless explicitly stated otherwise, the nodes in each network are arranged by a Force-Direction algorithm that groups closely linked nodes. This algorithm treats each node as a charged particle that repels all other nodes, and each edge as a spring, pulling the nodes back together.

Several network maps were generated to visualize the general flow of information between different resource types and what kinds of resources are owned or used by the federal government for emergency management. These network maps also explored two attributes of the network, betweenness centrality and resource connectivity.

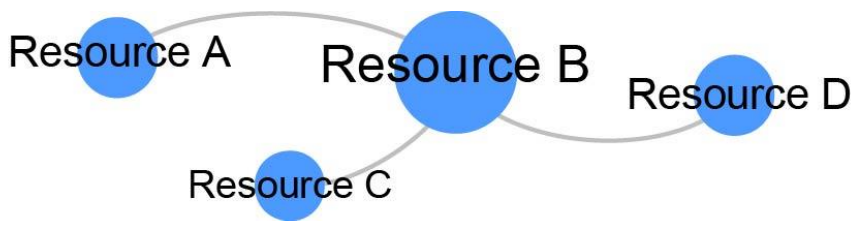

Figure A5.2. Example of a simple network map. Individual resources are represented by blue discs (nodes). Direct connections between resources are represented by gray curved lines (edges). The flow of information travels clockwise. In this example, information flows into Resource B from Resources A and D. Information from Resource B flows into Resource C. The size of each node can convey additional information; for the network maps presented in this report, nodes are sized relative to the number of users of that resource.

Resource Type

Each network map (see Figure A5.2 for example) depicts the flow of information, with the nodes representing the seven different resource types. Each node is sized based on how many resources in the inventory are of that resource type. Edges represent a connection between resources of different types and are sized proportionally to the number of those connections.

Betweenness Centrality

The importance of specific nodes was also investigated using the betweenness centrality measure, which is a common centrality measure that characterizes how often a node is between other nodes in

users", a method that significantly increases the number of users for resources that fall in the Raw Data and Event Characterization categories, for example.

the network.[10,11] Specifically, the betweenness centrality of a specific node is calculated as the number of times that node appears on the shortest path between any other two nodes in the network, measuring the degree to which a node acts as an intermediary between other nodes. With betweenness centrality, the most important nodes are those that act as “shortcuts” or “bridges” between different parts of the network. However, betweenness centrality only considers the shortest paths between nodes and therefore gives no weight to alternative paths over which information could be passed within a network. In the network diagrams, nodes were colored on a gradient such that more central nodes were darker and less central nodes were lighter.

Resource Connectivity

Nodes in directed networks can further be characterized by their in-degree (the number of incoming edges or upstream resources) and out-degree (the number of outgoing edges or downstream resources). According to these measures, the most important nodes in a network are those that are directly connected to the largest number of other nodes, regardless of their position in context with the rest of the network. A node’s in-degree is defined as the number of nodes feeding into it (in the resource network, the number of upstream resources) and a node’s out-degree is the number of nodes it feeds into (the number of downstream resources). A node’s degree is the sum of its in-degree and out-degree, signifying the total number of connections that node makes to another node.

As another way to quantify a node’s relative importance, the nodes cumulative in-degree and cumulative out-degree are respectively defined as the number of nodes that lie upstream and downstream of it, whether directly connected or linked through intermediary nodes. These cumulative measures rank a nodes relative importance in the network based on its role as a source or sink of information. In the resource network, resources with high cumulative out-degree are sources or providers of information to a large number of other resources, while resources with high cumulative in-degree act as the sinks of information, relying on information from many supporting resources. For the network of owners, the cumulative in-degree and cumulative out-degree of owners are calculated as the sum of the cumulative in-degree and out-degree of the resources they own. This calculation helps characterize which organization are the sources and which are the sinks of information.

[10] Freeman LC (1977) A set of measures of centrality based on betweenness. *Sociometry*: 35-41

[11] Freeman LC (1979) Centrality in Social Networks Conceptual Clarification. *Social Networks* 1: 215-239

Appendix 6: Metadata Tags

Resource

Resources are named. An abbreviation/acronym is used if one exists.

Model/Data

All resources are categorized as either models or data. Models are defined as programs, algorithms, or sets of calculations which may be used for emergency management. Many models accept as input a type of data which they transform into another type to provide new information. Other models collate individual data resources to yield a new dataset with enhanced utility. Data are defined as repositories of information that may be used for emergency management. This definition of data encompasses tools which assist in the presentation or visualization of data without transforming the data itself. Resources that have both modeling capabilities and a repository of their output, or some other data feed, are tagged as both a model and data.

Hazard

Resources are tagged based on the hazards during which they can be used to inform operational decision making. One or more hazards can be tagged for each resource. Resources can be tagged as: hurricane, earthquake, tsunami, flood, tornado, chemical release, contagious outbreak, non-contagious outbreak, nuclear detonation, explosion, fire, radiological dispersion device, and industrial radiological release. Resources may be tagged with a single hazard or multiple hazards. Additionally, resources that support emergency planning and response for any hazard type are tagged as All-Hazards.

Cascading effects were not considered when tagging hazards. Users interested in the cascading effects of a given hazard would instead search the inventory for the secondary hazard directly.

Supported Core Capabilities, ESFs, and RSFs

The Core Capabilities are designations that represent a list of critical elements within the five mission areas (Prevention, Protection, Mitigation, Response, and Recovery) necessary for Emergency Management.[12] The Core Capabilities are used to assess both the capabilities and gaps over the entire federal interagency emergency management community. In order to facilitate this effort, resources are tagged based on which Core Capabilities they support. Each resource may be tagged as supporting one, more than one, or no Core Capabilities. Each resource was tagged with Core Capabilities it directly supports, in addition to those supported by any downstream resources.

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[12] (2011a) National Preparedness Goal. Department of Homeland Security

The Emergency Support Functions (ESFs) and Recovery Support Functions (RSFs) provide a coordinating structure for the key functional areas that are most frequently needed in response and recovery, respectively.[13, 14] Identifying the resources that directly support each ESF and RSF will allow emergency managers to ascertain which resources can be used to support their specific missions. Like the Core Capabilities, each resource may be tagged as supporting one, more than one, or no ESFs and RSFs. Resources were only tagged with RSFs if they were also tagged with the Recovery phase (see the 'Phase Specific Utility' subsection). Unlike the Core Capabilities, the ESFs and RSFs are directly used in coordination of federal disaster response and recovery. Therefore, it is only necessary to know which resources directly support each ESF and RSF, and these tags are not inherited from downstream resources as Core Capabilities tags are.

As described in their Framework documents, each ESF and RSF has one Coordinating Agency and one or more Primary Agencies chosen on the basis of authorities and resources. These agency assignments were used in ESF and RSF tagging to help users identify inventory resources useful for their missions. First, based on information from interviews and research, resources were tagged depending on whether those resources were expected to support ESF or RSF missions. In addition, resources were automatically tagged with the ESFs and RSFs for which their federal users were Coordinating and/or Primary Agencies. This approach ensured that the ESF and RSF tags were informed by both interview data and existing policies for emergency management.

Keywords and Resource Functions

In addition to the Core Capabilities, ESFs, and RSFs, resources are further characterized based on their function. Keywords are simple titles designed to describe the resources independently of the flow of information. Each resource may be tagged with one or more keywords. In order to provide a higher level of resolution for the functions of resources included in the inventory, the keywords are further split into categories based on the flow of information. Each resource may be tagged with one or more resource functions. These tags provide a succinct description of the utility of a resource, both with regards to situations for which the resource is relevant and how it is incorporated into the flow of information. Keyword definitions are listed below:

Keyword	Description
Agriculture and Natural Resources	Data and/or modeling capabilities directly relating to land use, land and agricultural products, contamination, or related issues.
Blast	Data and/or modeling capabilities directly relating to dynamics and effects of blasts from chemical or nuclear explosives.
Communications	Data and/or modeling capabilities directly relating to communications logistics and infrastructure.

13 (2008) National Response Framework. Federal Emergency Management Agency
14 (2011b) National Disaster Recovery Framework. Federal Emergency Management Agency

Debris	Data and/or modeling capabilities directly relating to debris build-up and removal.
Dispersion	Data and/or modeling capabilities directly relating to dispersion of a molecule or substance (e.g., a radionuclide, chemical agent, or pollutant) through the air or water.
Economy	Data and/or modeling capabilities directly relating to local and national economic factors.
Electromagnetic Pulse	Data and/or modeling capabilities directly relating to an electromagnetic pulse from a nuclear or non-nuclear source.
Energy	Data and/or modeling capabilities directly relating to power systems and infrastructure.
Evacuation	Data and/or modeling capabilities directly relating to the movement of populations away from areas affected by a hazard.
Fire	Data and/or modeling capabilities directly relating to urban and wildland fires.
Food	Data and/or modeling capabilities directly relating to food production and human consumption.
Human Health	Data and/or modeling capabilities directly relating to the physical and emotional well-being of people, both individually and on a population level.
Imagery	Data and/or modeling capabilities directly relating to remote sensing data including aerial and satellite imagery.
Infrastructure	Data and/or modeling capabilities directly relating to any infrastructure including, but not limited to, roadways, bridges, buildings, communication, railroads, and energy infrastructure.
Inundation	Data and/or modeling capabilities directly relating to inland and coastal flooding.
Logistics	Data and/or modeling capabilities directly relating to organization and utilization of equipment, personnel, facilities, and services.
Mass Care	Data and/or modeling capabilities directly relating to the sheltering, feeding, first aid, and general care of disaster victims.
Media	Data and/or modeling capabilities directly relating to information from traditional and electronic media.
Ocean Dynamics	Data and/or modeling capabilities directly relating to ocean fluid dynamics.
Population	Data and/or modeling capabilities directly relating to local and national populations and their characteristics.
Public Information	Data and/or modeling capabilities directly relating to the dissemination of information about an incident to the public.
Radiation	Data and/or modeling capabilities directly relating to radiation including environmental radiation, specific radionuclide decay, and fallout from a nuclear blast.
Safety	Data and/or modeling capabilities directly relating to the safety and protection of the general population from environmental threats, including the identification of impacted areas.
Search and Rescue	Data and/or modeling capabilities directly relating to urban and rural search and rescue operations.
Security	Data and/or modeling capabilities directly relating to the security and protection of the general population (e.g., law enforcement activities), including the identification of at-risk areas.
Ground Shaking	Data and/or modeling capabilities directly relating to ground-shaking and fault lines.
Supply Chain	Data and/or modeling capabilities directly relating to the production and distribution of goods and materials.
Temporary Housing	Data and/or modeling capabilities directly relating to temporary housing of displaced populations.
Topography and Bathymetry	Data and/or modeling capabilities directly relating to terrain and elevation both for on land and underwater.

Transportation	Data and/or modeling capabilities directly relating to transportation infrastructure, traffic flow, and the movement of people.
Weather	Data and/or modeling capabilities directly relating to observational weather data and weather forecasts.

Resource Type

Resource types are directly drawn from the flow of information categories. As outlined in the Phase II report, data are categorized as raw data, situational awareness data, impact estimates, and/or mission specific requirements, while models are categorized as event characterization models/analysis, consequence models, and/or decision support tools. Each resource may be tagged as one or more resource types. Modeling resources that are useful as multiple resource types can also have multiple tags. Multi-tagged modeling resources represent models that perform multiple, successive steps of data processing. Similarly, data resources that are useful as multiple resource types can have multiple tags.

Data Collection Method

There are three primary methods of data collection: instrumentation, reporting, and the use of social media and crowd-sourced data. Data that are collected, aggregated, and processed directly (i.e., not generated as the output of models) fall into one or more of these three categories. It is important to specify the methods used to collect the data within a resource because collection methods can influence the availability, accessibility, and error associated with the resource.

Instrumentation data are obtained through the use of instruments that are capable of recording repeated observations. Often, data collected by instrumentation is raw data and requires processing by event characterization models or analysis tools before it can be used in support of decision making. Successful collection and aggregation of instrumentation data requires investment in a data collection infrastructure, which must be developed and deployed before an event occurs in order to collect and transmit the data in real time.

Data collected through human observation or non-automated data entry are considered reporting data. These data include damage assessments, hospital records, and critical infrastructure locations. While many types of instrumentation data can be continually collected without the need for large numbers of personnel during an event, reporting data generally take longer to collect and aggregate, and they demand larger personnel investments. Thus, reporting data are typically available at a lower resolution and after a longer delay than instrumentation data.

Social media data, including crowd-sourced data, are also used to inform and validate operational models and decision support tools, though much less frequently than the other two types. There is considerable interest across the interagency to develop methods to use social media data to support decision-making in a way that accounts for the data’s inherent uncertainty. Particularly in instances where traditional data feeds are unable to address a question, social media has the potential to serve as a valuable resource. For example, “Did You Feel It?” is a crowd-sourced data collection tool owned by USGS that enables users to input information regarding their experience of an earthquake or ground-shaking event. Particularly in regions for which there are only limited seismometers deployed, such as in Virginia, the data collected through the crowd-sourcing program can and has been used to characterize events and improve regional fault line maps.

Owner

The agency, division, or group responsible for updating, maintaining, and validating a given resource is identified. As specific contact information and organizational structures may change over time, specifying the entity in control of a given resource will ensure that it continues to be accessible, regardless of personnel changes or reorganization within agencies. If a resource has more than one organization that is in control of the resource, both organizations are listed as an owner.

Users (Agency-Level)

Resources are tagged with known members of their user communities. Here, users are defined as federal level organizations who directly apply information from the resource in order to answer a policy- or operations-related question in support of their missions for emergency management. Therefore, for the purposes of this project, state and local governments as well as private sector or academic organizations were not considered users (with the one exception of the Red Cross).

It is necessary to note that, while it is informative to tag resources with their known users, this is not the only way to judge the utility or reliability of a resource. New or recently updated resources may be underrepresented due to a lack of familiarity within the emergency management community. Similarly, it is also useful to consider the quality control methods used to verify and validate a given data resource. In any case, identifying the existing user communities who regularly use specific information resources in support of decision making allows both users and producers of these resources to work together in a process of ongoing development, evaluation, and maintenance.

Upstream and Downstream Inventory Resources

Based on the understanding that data collection, analysis, and modeling is an iterative process, the data and models that lie upstream of a given resource (i.e., those that serve as inputs for that resource) are defined. Complementary to the upstream resources category, downstream resources list the data and models that are fed by a given resource. This information indicates the datasets and models that use the resource as an input. It is important to identify the data and modeling resources that are interdependent, as validity of any model relies heavily on the accuracy of its inputs.

Phase Specific Utility

To assist users in determining which inventory resources are most relevant to their missions, the resources are tagged with the phases of emergency management for which they are useful. The phase tags are planning, pre-event preparedness (only for advance-notice events), immediate response (within approximately 36 hours following the event), deployment, sustained response, and recovery. Resources are phase-tagged based on their potential uses, not only their known ones. Thus, a resource which has been used for planning but which could likely be used in the immediate response phase would carry both tags. A resource may be tagged by one or more of the listed phases.

Full Name

The full name of the resource is provided.

Summary

A brief summary of each resource is provided to capture key usage and feature information.

Access

The procedures or credentials necessary to view, use, or update a resource are also defined. Resources can either be open access (immediately available to anyone or only requiring a free, automatic registration) or limited access (which can include proprietary data, classified data, or data that requires permission to access). Each resource may only be tagged as limited access or open access. These two tags are mutually exclusive.

Access Information

Detailed information regarding how to access the resource is provided.

Access Type

There are three primary ways a model can be run: standalone, through a reachback capability, or through interaction with a subject matter expert. Every model is tagged as one or more of these three access types. If a resource can be run through multiple sources, then it is tagged appropriately.

A model tagged as standalone describes any resource that can be run by any individual with access. Standalone access can include access through a web portal. A model tagged as a reachback capability is accessed through a reachback facility. This tag refers to resources run and managed by specific organizations and accessed through formal Requests for Information. A model tagged as subject matter expert is defined as any model that can only be accessed through personal interactions with the model developer or owner. Often, the outputs from these models can be accessed by the public online but the model itself is restricted for use by the subject matter expert. Models are also tagged as subject matter expert if they are run on a schedule based on computing limitations that precludes additional runs of the model outside the set schedule.

Processing Requirements

The processing requirements for viewing a data resource or running a model are defined as one or more of four categories: supercomputer, desktop/laptop, web-based application, and mobile device. Web-based applications are resources that can be accessed through a web portal. Resources are only tagged with 'mobile device' if they have a dedicated mobile application. Likewise, an Internet-based resource that could be accessed with a mobile browser is not tagged with 'mobile device' unless its website is optimized for mobile viewing. In certain cases, a resource may be tagged with two of the three processing requirements. For example, a weather model that can be run on a desktop computer but is often run on a supercomputer, would be tagged as both 'desktop/laptop' and 'supercomputer.' A supercomputer application accessed through a web portal would be tagged as both 'supercomputer' and 'web-based application'. A resource run on a desktop application with the same capabilities would be tagged with both 'mobile device' and 'desktop/laptop.'

Refresh Rate and Last Known Version

During all phases of emergency management, frequently updated resources are necessary to inform all levels of decision making. If the information is available, resources are tagged based on their refresh rate (how often they are updated). For data resources, this category specifies how often new information is uploaded into the dataset. For models, it indicates whether the model is routinely run, and if so, how frequently.

Not all data used to support decision making during emergency management can or should incorporate real-time data. While observational weather data must be updated every few minutes to reflect current conditions, data regarding the locations of critical infrastructure or residential building codes do not require the same update frequency to be operationally relevant. For datasets that do not consist of real-time data, the last known version of the dataset (often a release date) is indicated.

Similarly, not all models can or should be automatically run. While automatically refreshing weather forecasts are required for up-to-date situational awareness, many of NOAA's weather forecasting systems are run on a predetermined schedule because of the processing limitations of their supercomputers. This means that many of these models can only be run on their predetermined schedule and cannot be run more frequently during activation. As with datasets, the last known version of the model is indicated to ensure users are aware of the most recent release.

Programming Language

When possible, the programming language in which a resource is coded is given. This metadata category is not only important for developers interested in updating, modifying, or adapting a resource, but it may also provide essential compatibility information, indicating whether or not a resource can operate on a certain computer platform.

Output File Types

If relevant, the file type for a data resource or the file type for the output of a model is given. This information can be used by a model developer or analyst when determining data compatibility or other technical issues. It can also be used to indicate software requirements. If resources are capable of outputting multiple file types, then every file type it is capable of creating will be listed.

Technical Contact and Contact During Activation

The contact information for the group or individual responsible for updating, maintaining, or granting access to each resource is provided. When possible, coordinates for specific individuals are listed. Contact information always contains the organization or agency and, if applicable, the division of the contact in case of personnel changes. Where applicable, an additional contact is listed for use during activation.

Website

The resource's official website is provided where available.

Appendix 7: Data and Models Resource Catalog

The resource inventory is attached separately as an Excel table.